The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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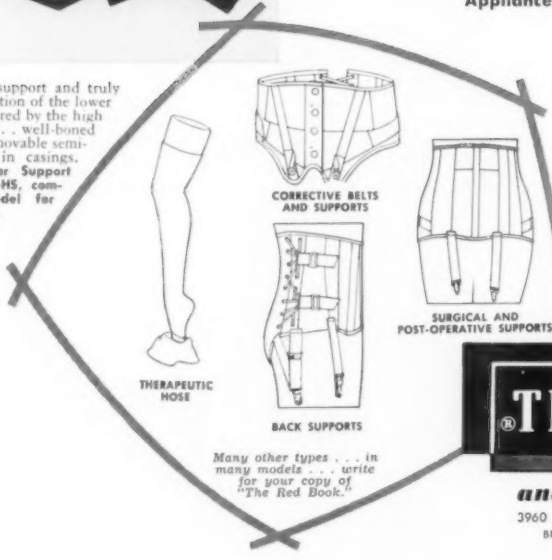
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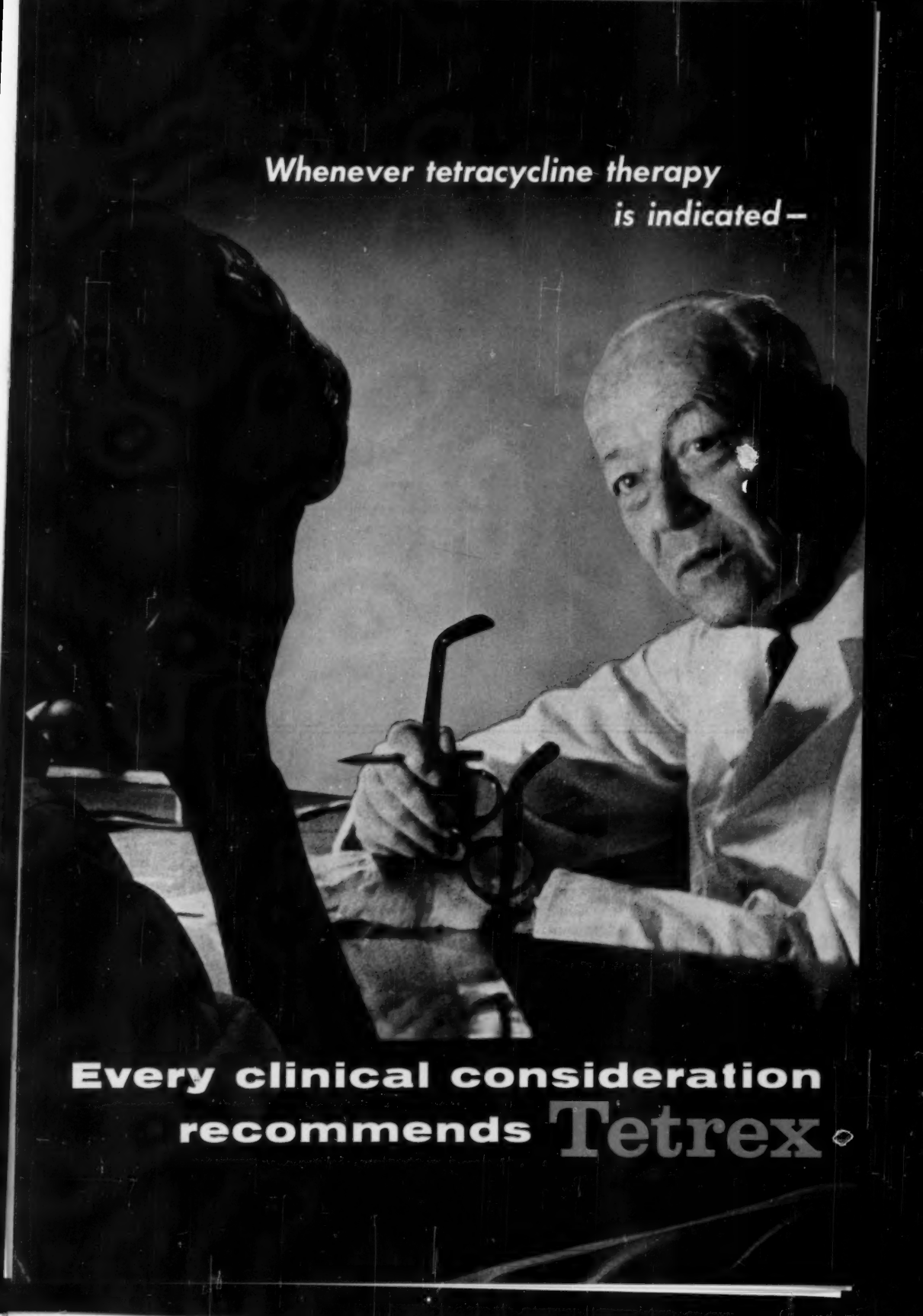
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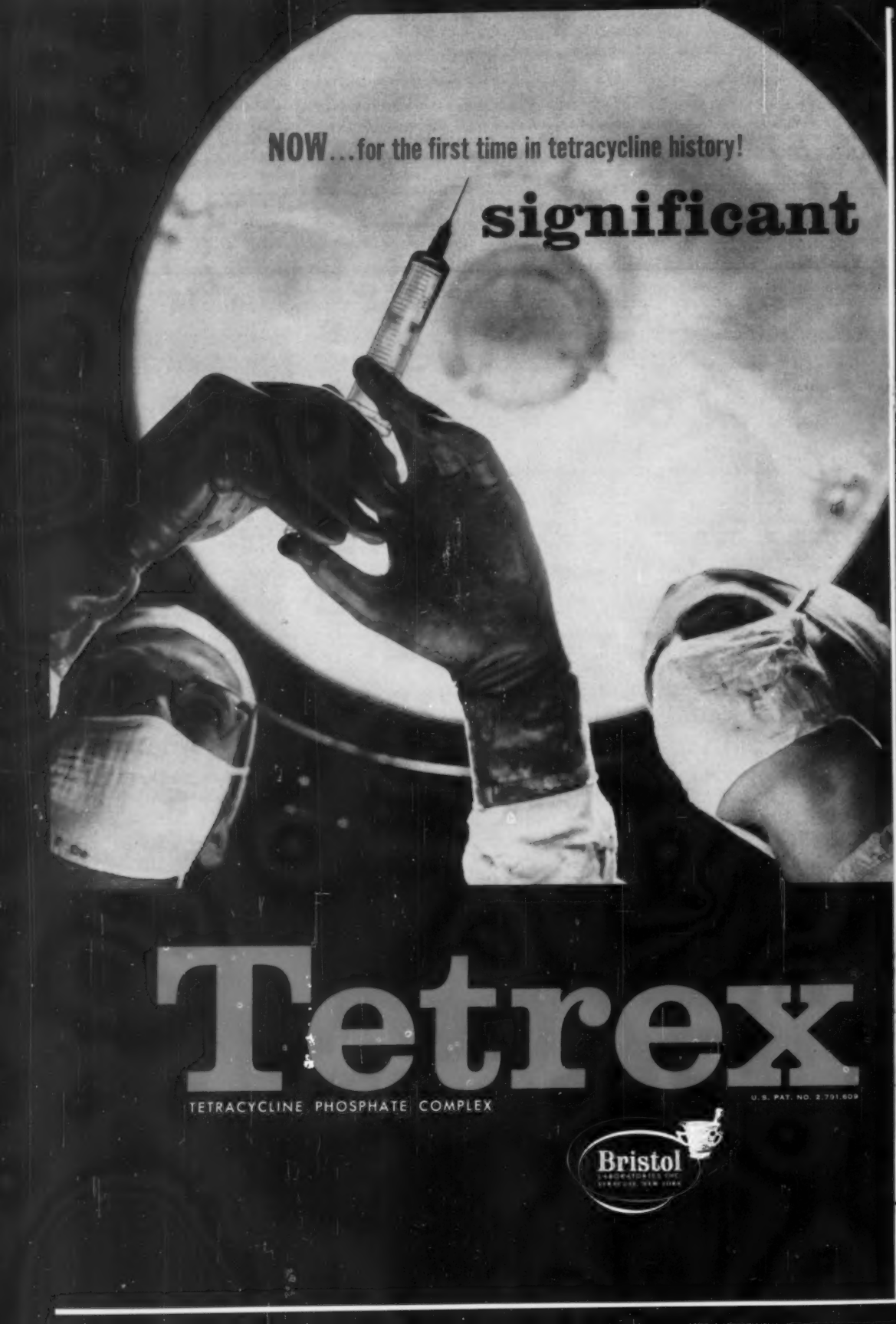
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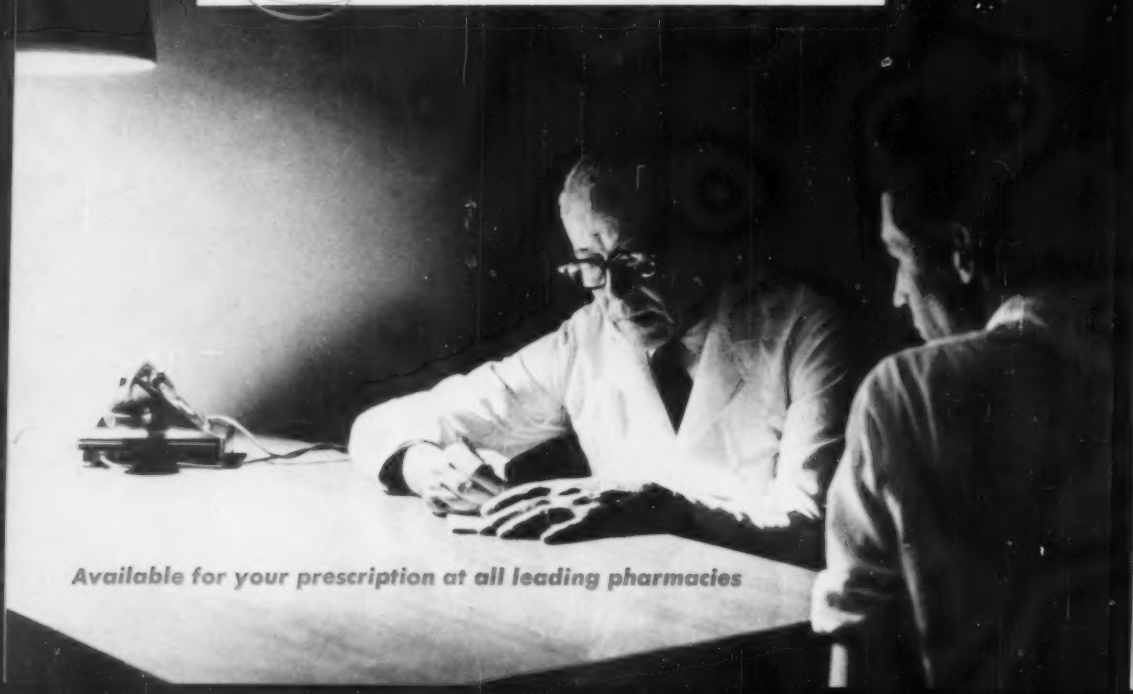

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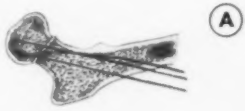
1 The legs are extended in moderate traction n a fracture table, the affected leg being held n traction in the long axis of the body and the ther leg abducted to permit adjusting the lateral -ray machine.

2 The fractured leg is forcefully rotated in- ernally until the greater trochanter lies parallel o the floor, thus impacting the fragments in the ateral plane.

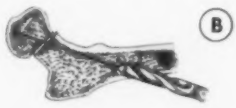
3 While moderate traction is applied to both egs, a sharp medial thrust is given the femur ust distal to the trochanter and this pressure is naintained while all traction is released from the ontralateral leg. This routinely produces a slight algus position of the affected leg.

4 A 4" expanse of femoral shaft is exposed eginning 1" below the lip of the trochanter.

5 Three guide wires are inserted at ⅝" intervals beginning 2" below the trochanteric lip through 7/64th drill holes made by using the sliding nail as a drill (6" drill length) guide when applied to the femoral shaft in the reversed position. Application of the plate also in the reversed position, enables the operator to align the nail exactly in the center of the neck in lateral view and to drill the holes at exactly 155°.



6 A trial film indicates the guide wire of choice to lie on the medial trabeculations in AP film or slightly posterior to midline in lateral film, and a ½" hole is reamed along this wire with a ½" reamer.



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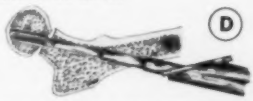
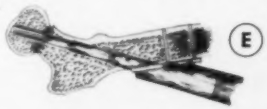
7 With the nail fully extended with the inserter in place, the nail and barrel are easily inserted so that the nail approaches the cortex of the proximal fragment. An x-ray is taken.

The plate is thrust distally under the vastus, lateralis, then slipped into place over the grooves of the end of the barrel.



The barrel with the plate attached is driven against the femoral shaft with the impactor. Two screws are inserted. If the nail requires further penetration after examination of the x-rays, this is done.



8 Finally, with all traction removed from both legs, the distal fragment is firmly impacted against the proximal fragment. This results in firm immobility, eliminates interfragment rotation, and seemingly greatly accelerates bone healing.

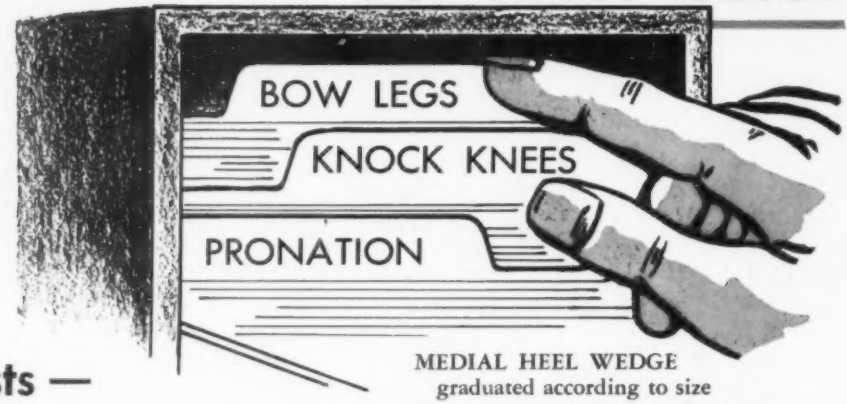
zimmer

LOOK FOR THE TRADEMARK (Z)

ZIMMER MANUFACTURING CO. • WARSAW, INDIANA, U. S. A.

Child Life
ARCH FEATURE SHOES

Most Adaptable For These Cases



Lasts —

CHILD LIFE Arch Feature lasts are made on "Normal Straight Last" lines with allowance on the medial side of the heel to accommodate the basic wedge which is built into the shoe as it is manufactured. The lasts, which have a heel two widths narrower than the ball, are graded in size from AA - EEE; 3½ infant's to misses size 3.

Construction —

Because the shoe is constructed with the basic features listed below, there is need for less additional wedging, and distortion of the shoe is held to an absolute minimum.

GOODYEAR WELT
allows additional wedging

CHROME LEATHER SOLES
finest, best wearing leather

FULL THOMAS HEEL
made of specially compounded rubber

LONG INSIDE LEATHER COUNTER
molded contour for added support

MEDIAL HEEL WEDGE
graduated according to size

RIGHT AND LEFT STEEL SHANK
triple ribbed tempered steel spring

Price —

Because the basic features of the shoe are built-in at the factory, the cost of your adaptation is a small added amount. It means a lower price to the patient and provides many features which could not otherwise be provided — certainly not by a "regular shoe."

Suggested Retail Prices	7.50 —	3½ to 6
	8.50 —	6½ to 8
	9.50 —	8½ to 12
	10.50 —	12½ to 3

Competent Shoe Fitters

The authorized CHILD LIFE dealer in your community has been selected for his knowledge of shoes and his ability to fit juvenile feet correctly. He is particularly qualified to accept your prescription work, and follow your instructions. Write for his name, and for the CHILD LIFE service booklet for the professional man, featuring representative shoes and wedging procedures.

HERBST Shoe Manufacturing Company Milwaukee 45, Wisconsin

now combined: muscle relaxant and analgesic

FLEXILON*

links FLEXIN* Zoxazolamine† "...a valuable lissive agent in voluntary muscle spasm of spinal or orthopedic origin"[1]

with TYLENOL* Acetaminophen, an effective analgesic for the treatment of musculoskeletal conditions.[2]

In common orthopedic and rheumatic conditions, FLEXILON promptly and safely relaxes spasm of the skeletal muscle and relieves pain.

supplied: Tablets, enteric coated, orange, bottles of 50. Each tablet contains FLEXIN, 125 mg., and TYLENOL, 300 mg.

and when a steroid is indicated...

FLEXILON-HC

(FLEXIN + TYLENOL + Hydrocortisone)

provides the anti-inflammatory benefits of hydrocortisone with the spasmolytic and analgesic effects of FLEXILON.

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references: (1) Settel, E.: Am. Pract. & Digest Treat. *8*:443, 1957. (2) Batterman, R. C., and Grossman, A. J.: Federation Proc. *14*:316, 1955.

*Trade-mark
†U. S. Patent Pending

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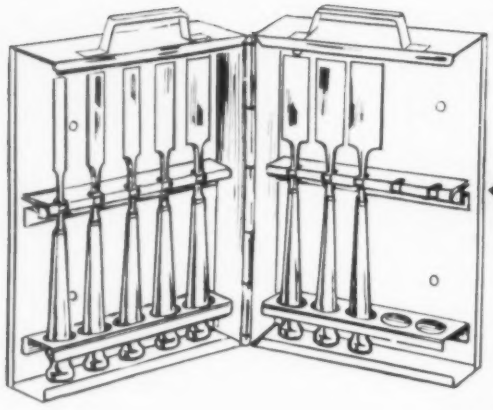

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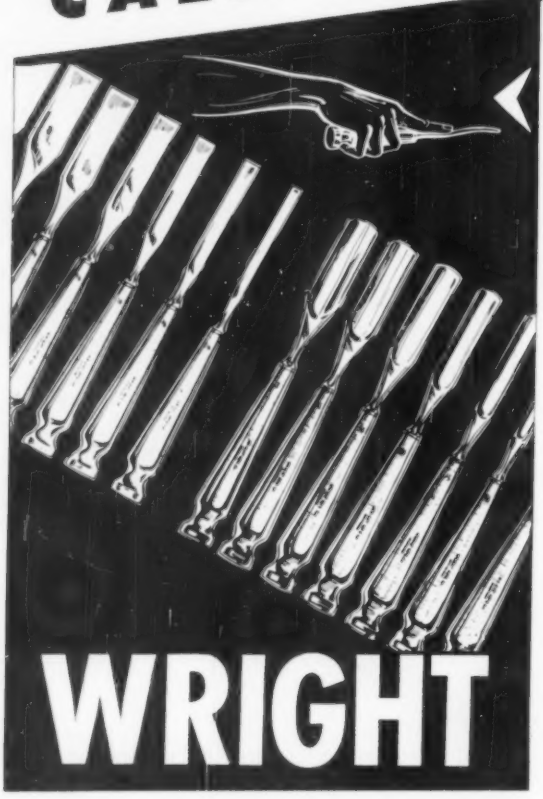
Caldwell osteotomes and gouges are balanced and matched to perfection . . . . made of the finest grade stainless steel and correctly tempered to hold extremly sharp cutting edges.

CALDWELL OSTEOTOMES GOUGES



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GRADUATED IN INCREMENTS OF 1/8" WIDTHS (¼" thru 1")

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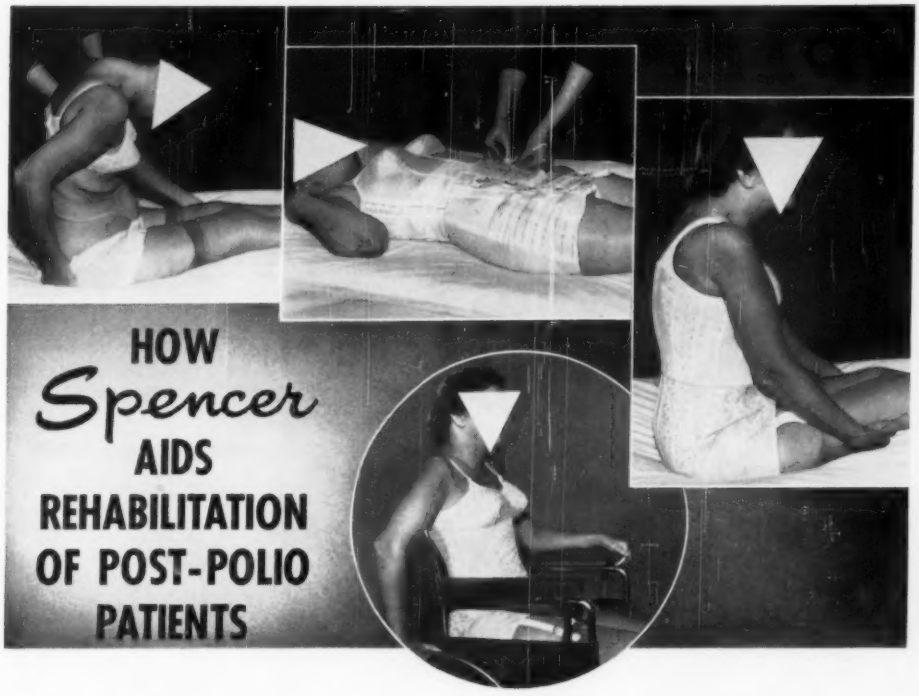

Eighty per cent paralyzed by polio, this young mother breathes diaphragmatically with only 50 per cent diaphragmatic function. Breathing was difficult in her old brace, causing physical exhaustion after a few hours in her wheel chair.

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Complete unit fits conveniently in a single foam rubber lined carrying case.

Sagittal Plane Saw

This saw is ideal for reaching narrow and / or deep locations where visibility is difficult and area prohibits easy access with other types of saws.

The interchangeable blades (shown) oscillate at the end of the narrow 2½" protruding arm. They interchange quickly without tools. Blades mount at angles up to 90° from shaft.

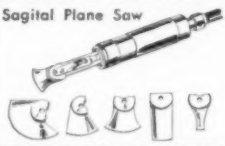
Ask for the Stryker Sagittal Plane Saw on approval— write today.

Bone Saw
$90.00

Rolo-Dermatome
$148.00

Rotary Handpiece
$75.00

Sagital Plane Saw



The Bone Drill Handpiece Operates each of these tools:

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$24.50

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MULTIPLE COMPRESSED TABLETS

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The first meprobamate-prednisolone therapy

the one antirheumatic, antiarthritic that simultaneously relieves: (1) muscle spasm (2) joint inflammation (3) anxiety and tension (4) discomfort and disability.

SUPPLIED: Multiple Compressed Tablets in three formulas: 'MEPROLONE'-5—5.0 mg. prednisolone, 400 mg. meprobamate and 200 mg. dried aluminum hydroxide gel. 'MEPROLONE'-2—2.0 mg. prednisolone, 200 mg. meprobamate and 200 mg. dried aluminum hydroxide gel. 'MEPROLONE'-1 supplies 1.0 mg. prednisolone in the same formula as 'MEPROLONE'-2.

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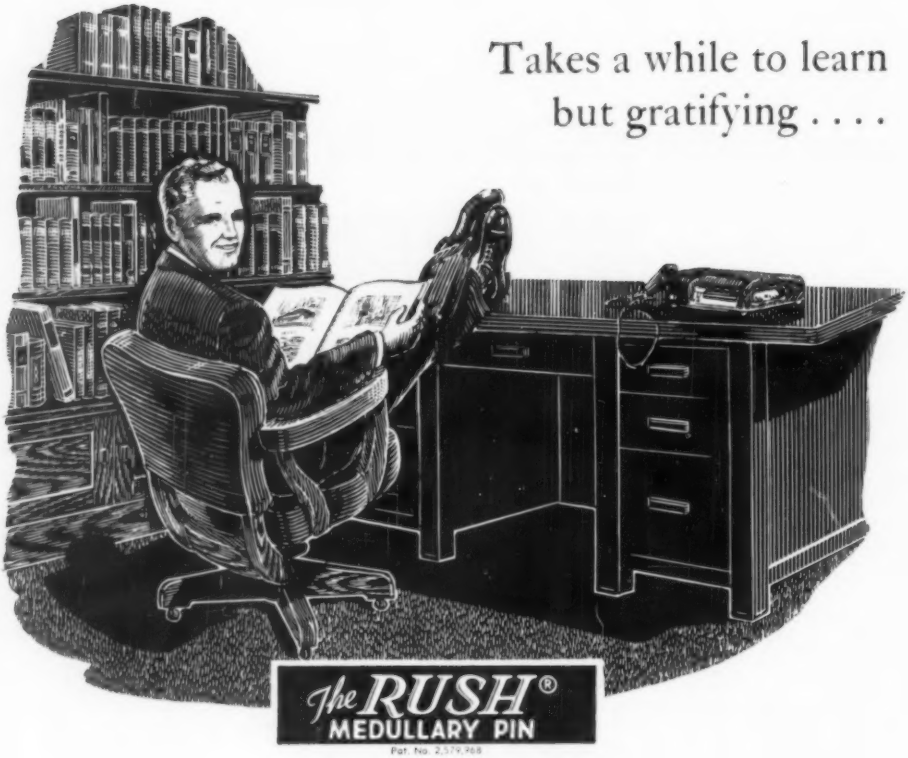

Proper application of the RUSH PIN is not always easy. It takes a while to learn. It is quite different in principle and technic from other forms of medullary fixation. It is not designed to impact the marrow cavity, but to accurately transfix the fractured bone by points of pressure, precisely applied.

The ingenious surgeon, who has added this to his knowledge and skills, has simplified his tasks and contributed pleasure to his patients. He minimizes surgery and speeds convalescence with unbelievably early motion, even in fractures near joints. Removable splints are sometimes used, but casts or traction, rarely.

The patient is more comfortable, the hospital stay is shortened. And best of all, the recovery time and residual disability can be markedly lessened.

It does take a while to learn, but it IS GRATIFYING!

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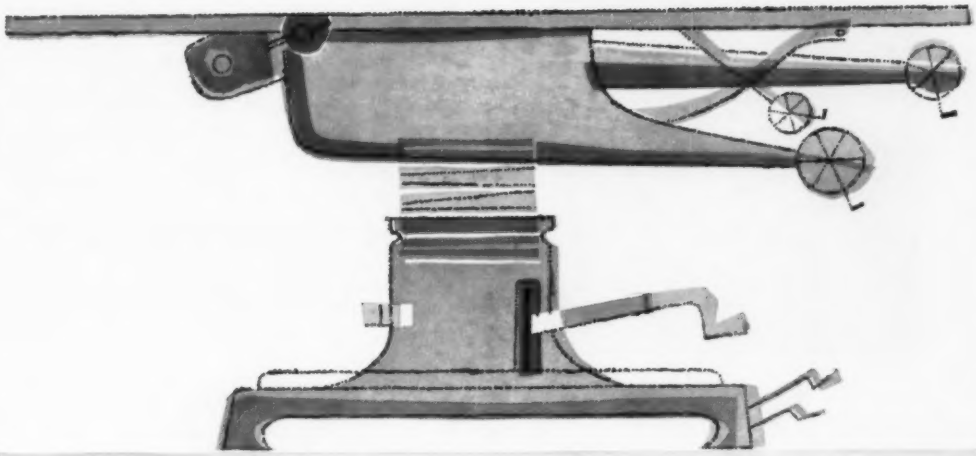
EXCLUSIVE MANUFACTURERS OF **RUSH** MEDULLARY PINS AND INSTRUMENTS
Publishers of **"ATLAS OF RUSH PIN TECHNICS"** by LESLIE V. RUSH, M. D.

do you have an overweight patient?



'Dexamyl' (a combination of dextro-amphetamine sulfate, S.K.F., and amobarbital) can smoothly and subtly encourage your patient to hold to the diet you suggest—thereby helping him get ready for surgery. (Furthermore, 'Dexamyl' is useful postoperatively; its mood-ameliorating effect encourages early ambulation.)

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tablets • elixir • Spansule† capsules

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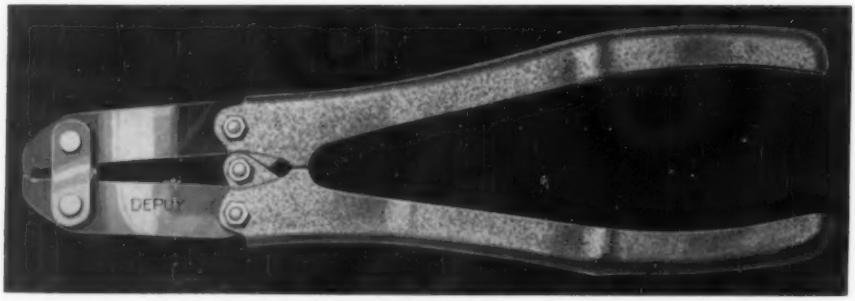
The First Completely Adjustable Intertrochanteric Bone Plate!

The new DePuy Universal Bone Plate is designed to provide both vertical and lateral angulation. In use with conventional Smith-Petersen Nails, cannulated or non-cannulated, or with Lorenzo Screws, it can be regulated quickly and easily during surgery to suit a wide variety of anatomical conditions. Bending of the plate is not required. A range of 35° in the vertical plane of the plate and nail or screw compensates for variance of angle between the femoral head and shaft of the femur. Also, there is a 15° range of lateral adjustment which permits the plate to be moved into flush position after the nail or screw has been impacted. Once angulation is properly adjusted rigid fixation is assured by exclusive concave, serrated locking washer, which is held in place with either the double locking screw combination or a solid Hex bolt. Finest SMO stainless steel. **No. 693.**

DePuy PIN CUTTER



The new DePuy Pin Cutter is designed to meet the need for a powerful end cutter that can cut the pin off flush. This sturdy instrument easily cuts pins up to 3/16″ diameter. The jaws are made of especially hardened tool steel to insure long life. The handles, made of plated steel, connect to the jaws through a powerful cam that permits easy operation even when cutting larger size pins. **No. 686.**

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This card entitles
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This new HANGER Service Card is tangible evidence of an old established HANGER policy. It introduces the client to any HANGER facility where he may secure whatever help he needs. It is his guarantee that any service required will be attended at any HANGER office, all listed in local telephone directories.

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and many other situations
in which advantageous use can be made of
"...the shortest-acting thiobarbiturate so far...."[1]

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Bibliography:
(1) Boone, J. D.; Muñoz, R., and Dillon, J. B.: Anesthesiology *17*:284, 1956. (2) Zima, O.; von Werder, F., and Hotovy, R.: Anaesthesist *3*:244, 1954. (3) Mersch, M. A.; Clarie, D'A., and Fitzpatrick, L. J.: J.M. Soc. New Jersey *53*:414, 1956. (4) Blake, M. W., and Perlman, P. L.: J. Pharmacol. & Exper. Therap. *117*:287, 1956. (5) Irwin, S.; Stagg, R. D.; Dunbar, E., and Govier, W. M.: J. Pharmacol. & Exper. Therap. *116*:317, 1956. (6) Ayd, F. J., Jr.: Neraval: A new anesthetic for electroconvulsive therapy, Paper presented at annual meet., Electroshock Research Association, Chicago, Illinois, April 29, 1956. (7) Reifferscheid, M., and Dietmann, K.: Deutsche med. Wchnschr. *79*:638, 1954. (8) Houde, J.; Hudon, F., and Jacques, A.: Neraval (methitural sodium), Paper presented at Meet., Canad. Anaesth. Soc., Quebec City, P. Q., May 5, 1956.

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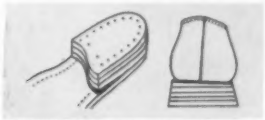
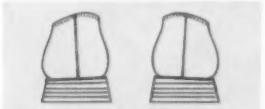
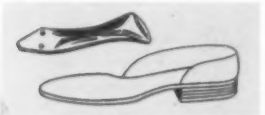
Poll-Parrot Vita-Poise shoes with these *Tru-Guide* features:



TRU-GUIDE BROAD-BASE LEATHER WEDGE HEELS BUILT FOR EASY ADJUSTMENTS



INDIVIDUAL LEFT AND RIGHT QUARTERS CONFORMING TO CHILD'S ANKLE BONES



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construction features you want

***plus* the styling mama wants!**

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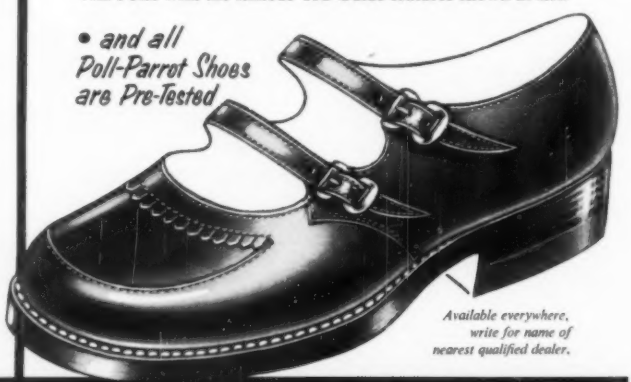
• *and all Poll-Parrot Shoes are Pre-Tested*



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Poll-Parrot *Vita-Poise* Shoes

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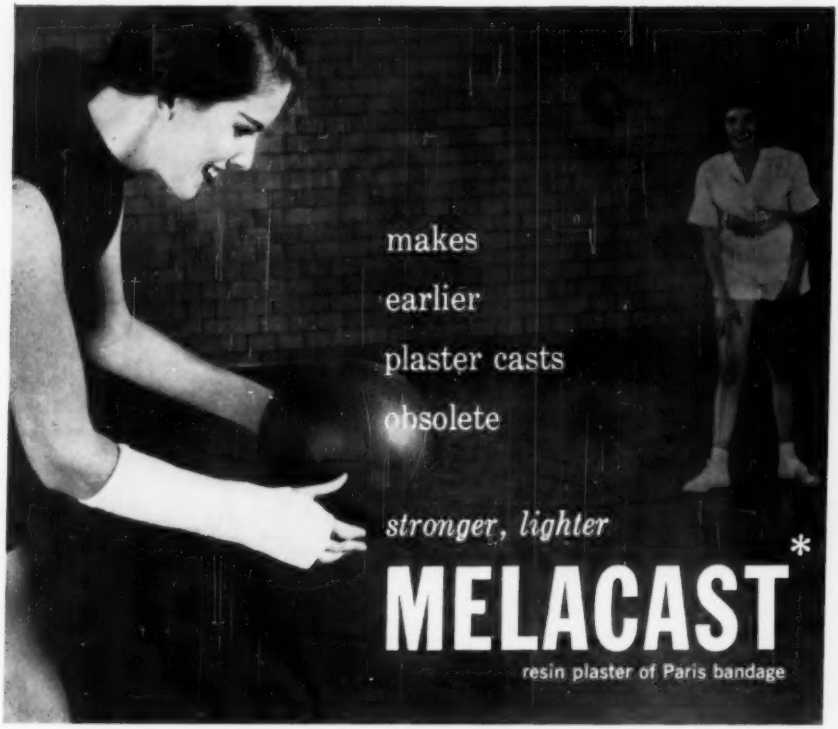

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ready to use – just dip, squeeze and apply... requires half as many bandages as ordinary plaster casts

correct drying action – no waiting... allows trimming time, then hardens to full strength promptly

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costs less per cast than plain plaster!

Next time you need plaster bandages, specify modern, easier-to-use MELACAST in the new, plastic-lined moisture-proof package... another outstanding development from Surgical Products Division.

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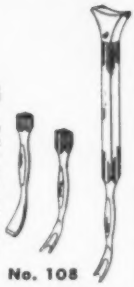
Used through any arthrotomy exposure and on either semilunar cartilage, it guarantees the integrity of all structures within the joint and permits complete removal of either meniscus.

Designed like a large intra-uterine curette, it presents a smooth rounded guard on the outer surface of the ring, the inner margin of which is a keen knife edge permitting cutting in any direction. Its use will shorten by about one-third the present operating time.

Standard Length: 8½″ • No. 128

Smillie Cartilage Sets

Designed with handles that do not obscure field of vision. Longer back always rests on tibial table. Beaked knife divides the peripheral attachments of the medial meniscus. Also divides the central attachment of the posterior horn of the lateral meniscus. Second beaked knife used for the same purpose, also to divide the central attachment of the posterior horn of the medial meniscus. Chisel mobilizes middle third of the meniscus.



No. 108
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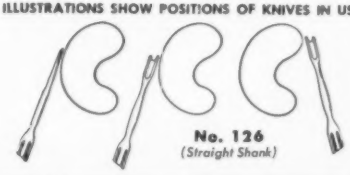

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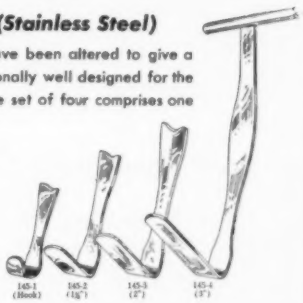

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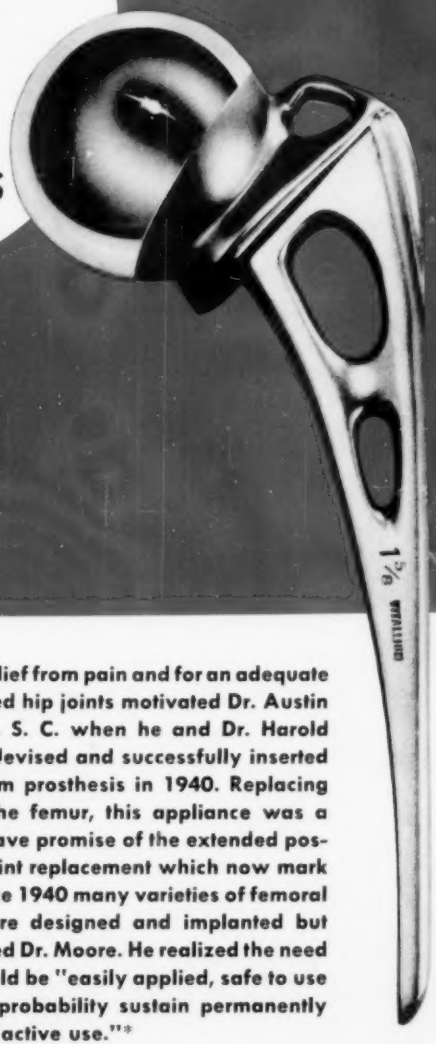

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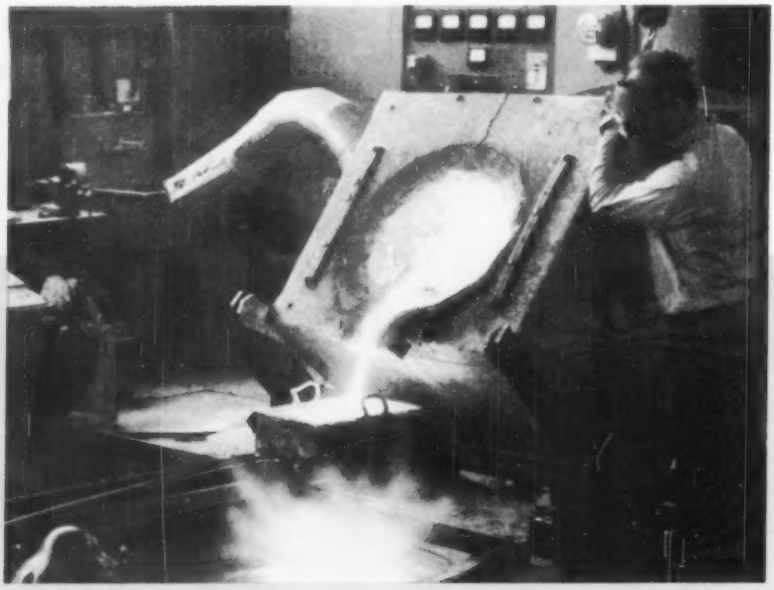

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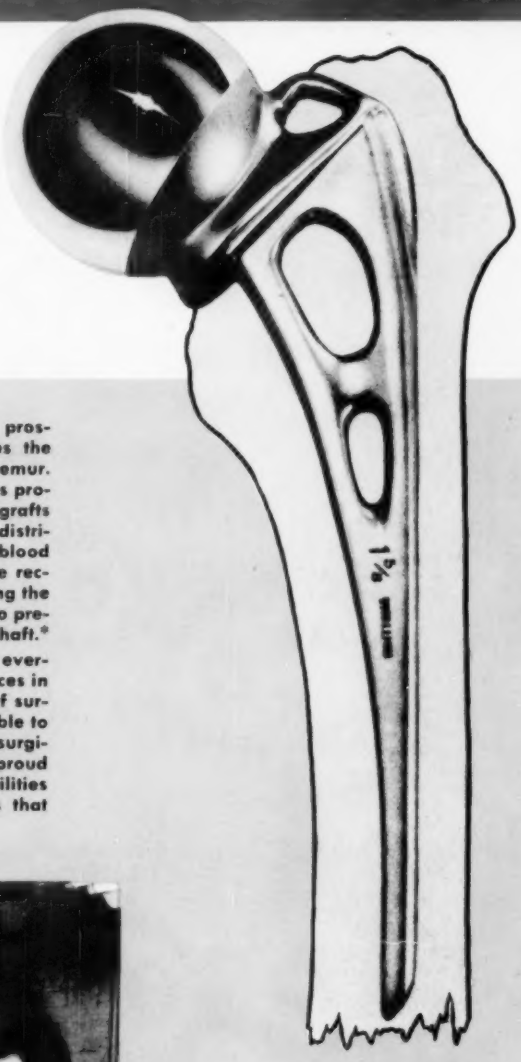

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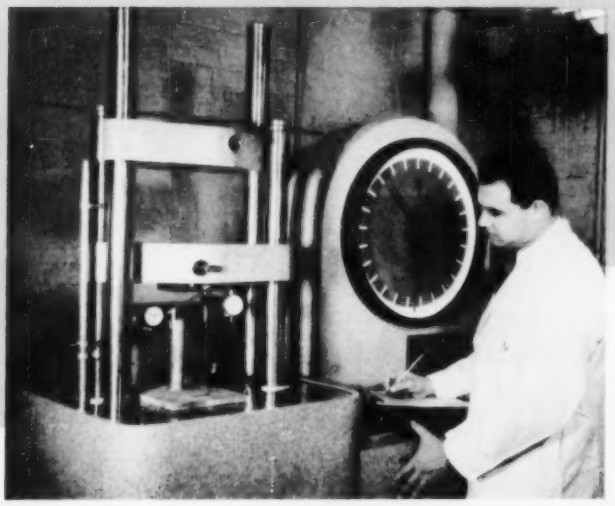

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*Moore, Austin T.: Metal Hip Joint, A New Self-Locking Vitallium Prosthesi South. Med. Journ. 45: 1015-1019 (Nov. 1952).

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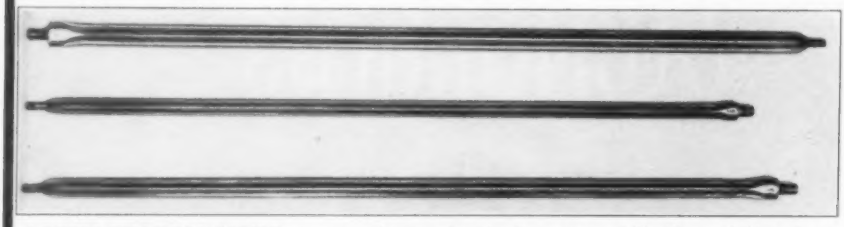

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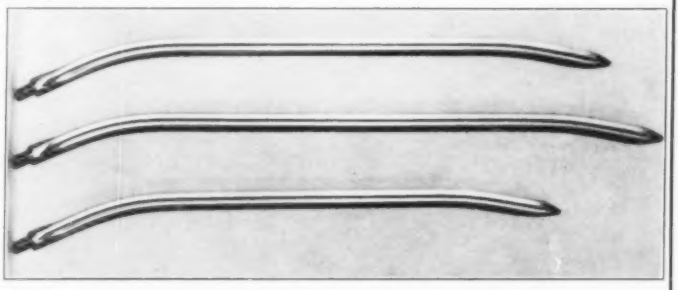

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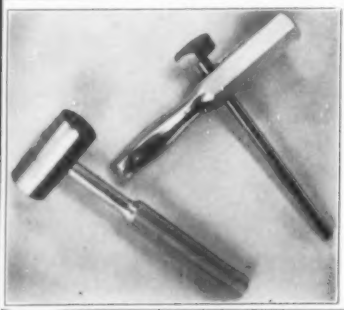

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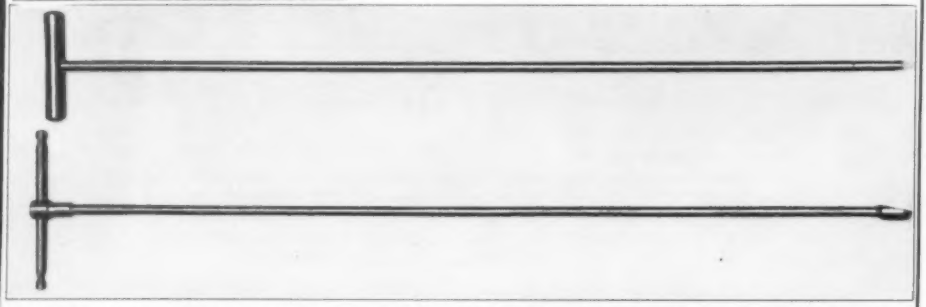

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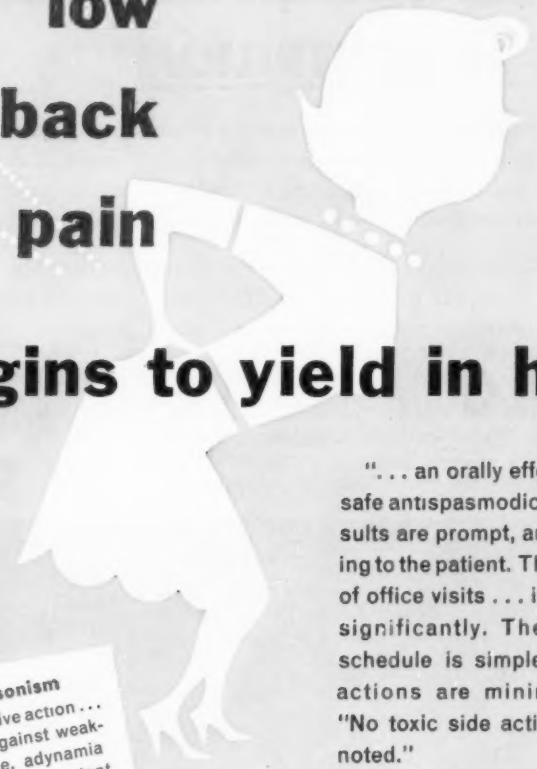

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Finch, J. W.: Orphenadrine (Disipal) in Skeletal Muscle Disorders. To be published.

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references (1) Settel, E.: Am. Pract. & Digest Treat. 8:443, 1957. (2) Johnson, H. J., Jr.: Am. Pract. & Digest Treat., in press. (3) Council on Pharmacy and Chemistry, A.M.A.: New and Nonofficial Remedies, Philadelphia, J. B. Lippincott Company, 1957, p. 508.

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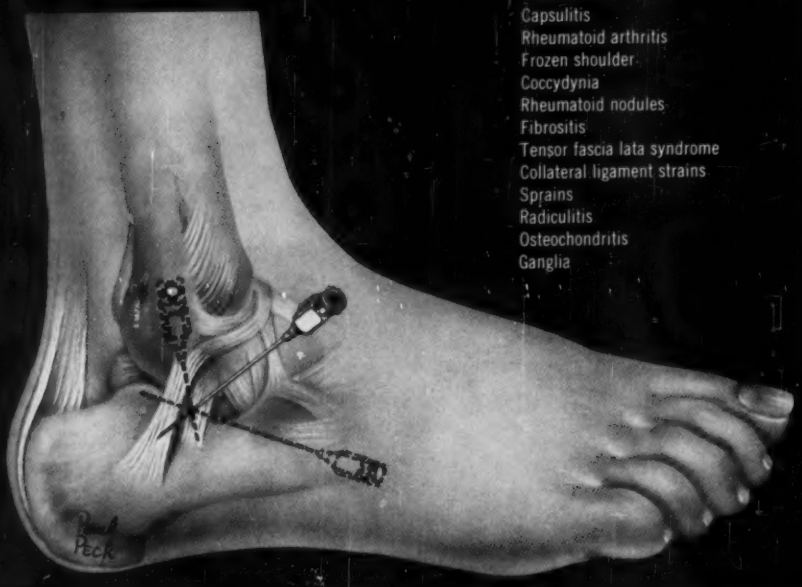

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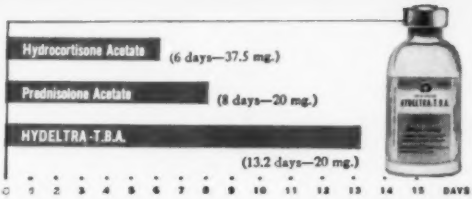
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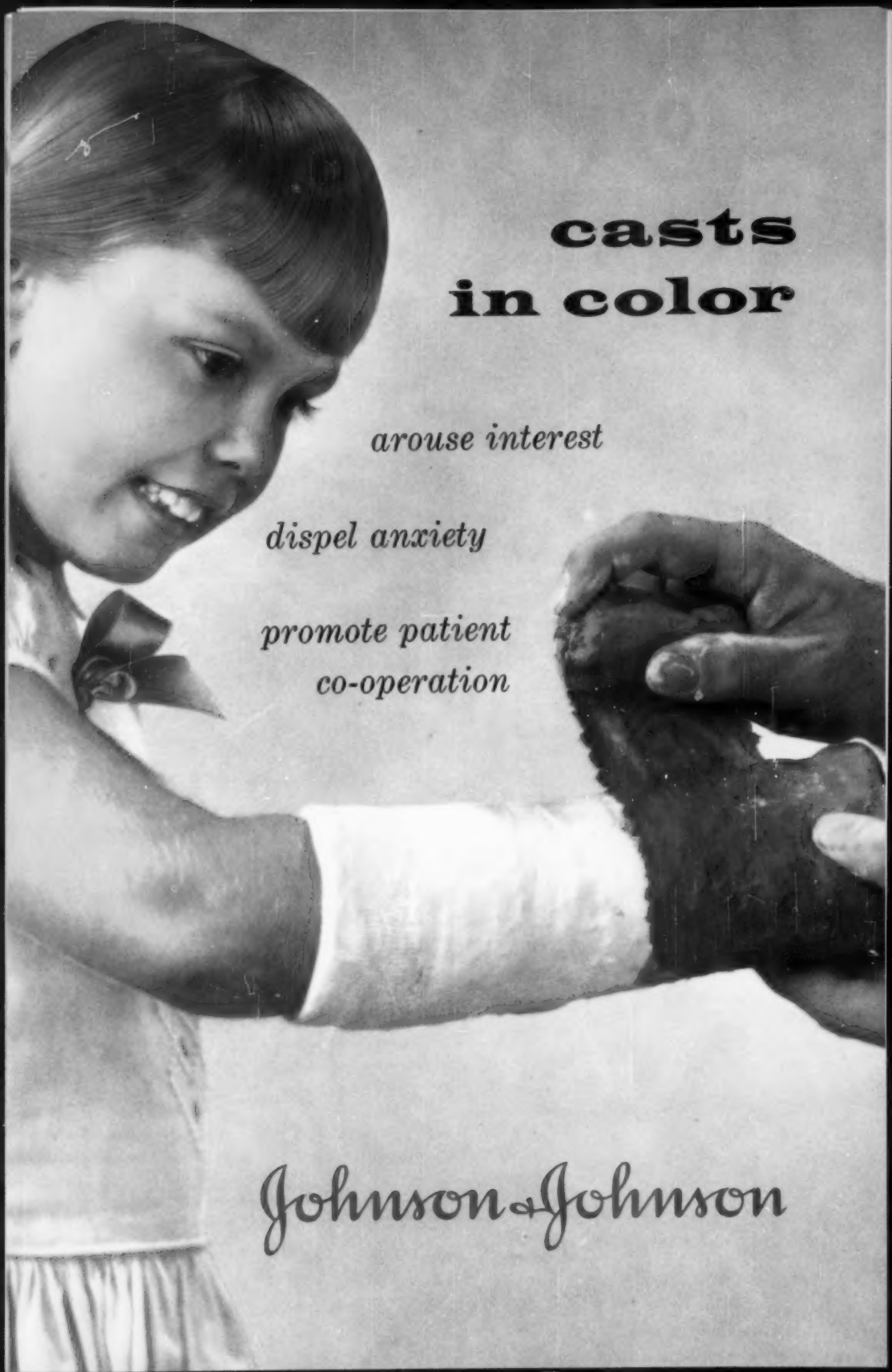
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The Journal of
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American Volume

Congenital Absence of the Fibula *

BY T. CAMPBELL THOMPSON, M.D., LEE RAMSAY STRAUB, M.D.,
AND WILLIAM D. ARNOLD, M.D., NEW YORK, N. Y.

From the Hospital for Special Surgery, New York

It is the purpose of this paper to review thirty-one instances of congenital absence of the fibula occurring in twenty-five patients. In particular, we wish to emphasize the consistent pattern of the deformities in each patient, the presence of a tight deforming band replacing the absent fibula, and finally, the effect of early excision of this band. The patients studied were observed and treated at the Hospital for Special Surgery from 1939 to 1955.

The term *congenital absence of the fibula* has generally described an anomaly characterized not only by absence of the fibula but also by tibial bowing, deficiency in growth of the extremity, and deformities of the foot. Harmon and Fahey, Coventry and Johnson, Freund, and others within recent years have reviewed this anomaly. Harmon and Fahey, in 1937, were able to cite forty-eight prior references. Most of the earlier orthopaedic textbooks include some description of this condition. Although uncommon, it is not rare in clinics dealing with large numbers of orthopaedic patients.

The etiology of the condition is obscure. Most studies point to the defect as an acquired anomaly occurring as a result of an accidental injury to the embryo at about the sixth or seventh week. It is likely that some subtle insult is involved, possibly anoxia within the embryo, as suggested by Ingalls. Presumably there must be a defect in the scleroblastema involving the anlagen of the fibula, tarsus, and metatarsus, and perhaps of the tibia as well, although the tibial anomalies are conceivably the product of soft-tissue changes secondary to absence of the fibula. In this regard the work of Bagg is of interest. He was able to follow *in utero* the development of extremity anomalies in the descendants of irradiated mice. He noted first a vesicle forming at the site of later malformation, with progression to hemorrhage and final tissue destruction. Some of the anomalies observed by him and Bean in the descendants of irradiated mice, notably tarsal fusion, have their counterparts in the cases to be presented. Mention should be made of Middleton's hypothesis that a lesion of the limb muscle is responsible for the deformities of this anomaly. Although this could not be substantiated in this series, it is interesting to note the similarity of his concept of the deforming effect of shortened calf musculature with the deforming action of the tight band noted in many of the extremities in our patients.

There were eleven girls and fourteen boys in this series, most of whom were seen

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1957.

TABLE I

INCIDENCE OF CHARACTERISTIC DEFORMITIES IN THIRTY-ONE LIMBS WITH CONGENITAL ABSENCE OF THE FIBULA

Deformity	No. of Limbs
Gross shortening of extremity	31
Talipes equinovalgus	31
Absent fibula	30
Partial absence of fibula	1
Anterior tibial bowing	25
Medial tibial bowing	11
Tarsal anomalies	26
Metatarsal anomalies (absence of one or more rays)	26
Gross shortening of femur	17
Pretibial dimple	17
Tight band	18
Genu valgum	8
Webbing of toes	5
Other skeletal anomalies	5

first in infancy. The oldest patient in this group first presented herself for treatment at the age of eighteen. No hereditary factors could be identified, but there were several instances of spontaneous abortion immediately preceding or following the pregnancy producing the deformity. The component deformities of the anomaly are shown in Table I. It was of interest to note the similarity in the appearance of these patients and the frequency with which the major deformities occurred. The lower limb was short in every case, the femur frequently being involved in the total limb-length discrepancy. At full growth, if no effort had been made to equalize limb lengths, the discrepancy was usually ten centimeters or more. Within relatively broad limits, this discrepancy was predictable if the typical deformity were present. Even with operative correction, considerable difference in limb length remained. Talipes equinovalgus was consistently present; genu valgum and posterior displacement of the foot occurred less frequently. Bowing of the tibia was frequent. Anterior bowing, which occurred in twenty-five instances, was more frequent and pronounced than medial bowing. Although it has been stated [1] that there is a tendency for the bowing to decrease with growth, it was not obvious in the untreated cases in this series. In untreated adolescent patients, anterior bowing of from 30 to 45 degrees was seen. A pretibial dimple, present in seventeen patients at the apex of the tibial bow, usually occurred in the more severe deformities. The nature of the dimple is obscure, although Freund suggested that it represents the site of former adherence of the bowed tibia to the overlying skin. Tarsal and metatarsal anomalies occurred in nearly every instance; fusion of the talus and calcaneus was noted in eleven extremities. Delay in ossification was frequently seen in the affected extremity. In no instance, however, was there enough ossification to develop the congenitally absent fibula.

A tight band of fibrous or fibrocartilaginous tissue was present in eighteen extremities in the posterolateral portion of the calf extending from the calcaneus to the upper portion of the tibia. This was separate from the tendo achillis, which was also apt to be tight in these patients, and was frequently palpable. Little attention has been directed to this band in the past, although Harmon and Fahey described a dissection of such a band, and Freund stated that it was mentioned in the German literature as early as 1896 by Haudek. In eleven instances in this series the band was dissected and removed. In each case, it was found lying in the posterior and lateral area of the calf, lateral to the tendo achillis. The distal end was firmly attached to the posterolateral aspect of the calcaneus. Proximally the band was usually found attached to the lateral margin of the upper

TABLE II

RESULTS OF EXCISION OF CONGENITAL FIBROUS BAND IN TREATMENT OF CONGENITAL ABSENCE OF FIBULA

Patient	Age at Operation	Deformity	Age at Follow-up	Residual Deformity	Postoperative Status
M. V.	6 mos.	Sharp anterior tibial bowing; 30 degrees of talipes equinus; 90 degrees of talipes valgus	15 yrs.	No tibial bowing; no talipes equinus; moderate talipes valgus; 5½ inches of shortening	Walks well; dances with built-up shoe; rejects cosmetic amputation
L. B.	1 yr.	Sharp anterior tibial bowing; 20 degrees of talipes equinus; 45 degrees of talipes valgus	10 yrs.	Less than 10 degrees of tibial bowing; no talipes equinus; slight talipes valgus; 4½ inches of shortening	Full activity with brace
R. W.	4 mos.	40 degrees of anterior tibial bowing; 10 degrees of talipes equinus; 45 degrees of talipes valgus	10 yrs.	Less than 5 degrees of tibial bowing; no talipes equinus; moderate talipes valgus; 5½ inches of shortening	Full activity with brace; limited ankle motion
G. G.	3 yrs.	Rt. More than 45 degrees of anterior tibial bowing; 50 degrees of talipes equinus; extreme talipes valgus	15 yrs.	Slight tibial bowing; no talipes equinus; moderate talipes valgus	Full activity with brace on right limb; corrective shoe only on left foot
	7 yrs. (recurrence)				
	3 yrs.	Lt. 30–40 degrees of anterior tibial bowing; moderate talipes equinus; moderate talipes valgus		No tibial bowing; no talipes equinus; slight talipes valgus	Good function of transplanted peroneal tendon to anterior tibial tendon
F. B.	5 yrs.	30 degrees of anterior tibial bowing; 40 degrees of talipes equinus; slight talipes valgus	12 yrs.	No tibial bowing; no talipes equinus; no talipes valgus; 5½ inches of shortening	Full activity; stock shoe with raiser
B. S.	8 mos.	45 degrees of anterior tibial bowing; moderate talipes equinus; marked talipes valgus	5 yrs.	15 degrees of anterior tibial bowing; no talipes equinus; slight talipes valgus; 3½ inches of shortening	Full activity with brace
O. M.	7 mos.	40 degrees of anterior tibial bowing; moderate talipes equinus; moderate talipes valgus	9 mos.	Too early for evaluation; talipes equinus corrected postoperatively	
L. B.	2 yrs.	Rt. and Lt. 45 degrees of anterior tibial bowing; moderate talipes equinus; moderate talipes valgus	2½ yrs.	Too early for evaluation; talipes equinus corrected postoperatively	

portion of the tibia. The band was taut, firm, and inelastic and in several patients it contained bits of cartilage or even bone. In nearly every patient the foot could not be brought out of talipes equinus following division of the tendo achillis until this band had been divided as well. When the band was removed, it was always found in the location which the fibula would have occupied had it been present. Tissue resembling the interosseous membrane was present in several instances, extending from the tight band to the tibia. It seems reasonable to assume that this band represents the anlage of the absent fibula.

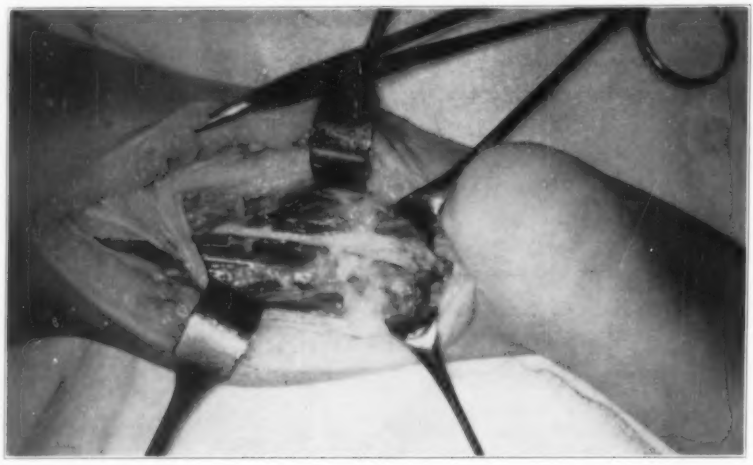

FIG 1

Photograph made at operation showing the tight band.

Of the thirty-one extremities forming this series, the band was present in eighteen. This was proved by dissection in eleven patients; in three others it was easily palpable. In four instances the operative description of an amputation inferred the presence of a band. Dissection failed only twice to reveal a band. In both of these patients the tibia lacked the usual anterior bow. Study of records of the eleven other extremities failed to indicate the presence or absence of a band.

Twenty-eight surgical procedures were performed in an effort to correct the deformities. Excision of the tight bands, together with tendo achillis lengthening and posterior capsulotomy of the ankle joint when indicated, was performed in ten extremities. These procedures were supplemented by transfer of the peroneal tendons to the dorsum of the foot in two patients. Tendo achillis lengthening alone was unsuccessful in two patients. Tibial osteotomies were done in five extremities, two of them to facilitate a Syme's amputation. Amputation was carried out in eight patients in whom the limb-length discrepancy was greater than five inches, except in one child who had bilateral involvement. In this instance tibial osteotomies had not provided satisfactory gait or cosmetic improvement. Epiphyseodesis on the normal leg was performed on two occasions. One of these operations followed resection of a portion of a hypoplastic fibula in the only patient in this series in whom there was partial absence of the fibula. In general, the limb-length inequality in these patients was too great to permit equalization by epiphyseodesis.

In ten extremities in eight patients the band was excised (Table II). Three operations on two patients have been performed too recently to evaluate the results, although the foot could be placed in a corrected position as soon as the band was excised. Of the remaining six patients (seven extremities), followed from five to fifteen years, the results have been satisfactory in terms of position of the foot. In each of these patients, the talipes equinus was corrected, the valgus deformity lessened, and the tibial bowing reduced. Considerable limb-length discrepancy remains, however. All of these patients now walk with ease and enjoy full activities in an elevated shoe or simple elevated brace (Fig. 2). The favorable results are doubtless related to the early age at which the band was excised. This operation was performed on children who were from three months to five years of age; most were under two years. Brief case histories of three representative patients subjected to early removal of the tight band follow.

CASE 1. M. V. This patient was first seen at three weeks of age. She had a typical anomaly. At six months a tough inelastic band, described by the surgeon as "acting like a bowstring," was removed. In addition, the peroneal tendons were attached to the anterior tibial tendon and a posterior capsulotomy of the ankle joint was performed. At a recent examination, fourteen years later, she had a satisfactory position of her foot and had lost the tibial bowing. She enjoys full activity in a raised shoe and both she and her parents rejected the proposal of a Syme's amputation (Figs. 3-A and 3-B).

CASE 2. L. B. This patient was first seen with a typical anomaly at the age of one year. At that time, a tight, thick band was excised and a posterior capsulotomy of the ankle joint, tendo achillis lengthening and resection of the distal two-thirds of the interosseous membrane were performed. Preoperatively, sharp angulation of the tibia was evident. Nine years later roentgenograms revealed nearly complete loss of the tibial bowing. There was no talipes equinus and the talipes valgus was much improved. At ten years of age, the boy had four and one-half inches difference between limb lengths. Should a Syme's amputation become necessary because of this inequality, the correction of the tibial bowing will still be of value (Figs. 4-A and 4-B).

FIG. 2

Congenital absence of the fibula in the right leg. Patten brace was used during the period of growth. There was limb shortening of five inches.

CASE 3. R. W. This patient, with a typical anomaly had excision of a tight band in the usual location at the age of four months. In this instance, a definite attachment of the band to the interosseous membrane was evident. The tendo achillis was also lengthened at this procedure. Roentgenograms postoperatively

FIG. 3-A

FIG. 3-B

Fig. 3-A: M. V. Congenital absence of the fibula in the right leg, with talipes equinovalgus and tibia bowing, preoperatively.

Fig. 3-B: Fourteen years following resection of the tight band.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Congenital absence of the fibula in the right leg, with talipes equinovalgus and tibial bowing, preoperatively.

Fig. 4-B: Six years following resection of the tight band, photograph and roentgenogram reveal correction of tibial bowing.

FIG. 5-A

FIG. 5-B

Fig. 5-A: R. W. Congenital absence of the fibula in the left leg, with talipes equinovalgus and tibial bowing, preoperatively.

Fig. 5-B: Ten years following resection of the tight band.

FIG. 6-A

FIG. 6-B

Congenital absence of the fibula in the left leg. Syme's amputation was performed when the patient was eighteen years old. She is wearing an end-bearing prosthesis.

and ten years later revealed the correction of the tibial bowing. There was no talipes equinus and the talipes valgus was lessened. The child played and had unlimited activity with a simple elevated brace. There was five inches of shortening at ten years of age, and a Syme's amputation will be performed within a few years.

DISCUSSION

For the past ten years we have advocated soft-tissue procedures, including excision of the tight fibrous band, at an early age. Many patients, especially as they approach adolescence, request amputation because of the degree of shortening of the limb, even though the bowing has been corrected by excision of the band. The Syme's amputation is much better than the standard below-the-knee type, as the latter often results in a thin, curved, atrophic stump. The slightly bulbous but short Syme's stump can be fitted into a standard below-the-knee prosthesis which matches the normal leg (Figs. 6-A and 6-B). If the stump is straight and good heel skin has been saved, end-bearing is possible as well. So far, operative scars have not interfered with the later fitting of a prosthesis. Amputation has been delayed until closure of the lower tibial epiphysis.

Conservative measures usually have little place in the treatment of this anomaly. Preoperatively, little has been gained by wedging plaster casts. Postoperatively, after correction of the talipes equinus, the limb is kept in plaster only until firm healing occurs.

If the ankle is stable, a shoe with the correct elevation will suffice for ordinary activities. In those patients with an unstable ankle and a short limb, a simple elevated brace has been employed. Occasionally, when the limb shortening is the principal deformity, these measures alone will suffice for satisfactory gait.

Since the similarity of these deformities is striking, we have not classified the anomalies into subgroups, but presented these limbs as examples of typical anomalies or as variants. Of the thirty-one deformed limbs in this series, twenty-six are classed as typical. Hypoplasia of the entire extremity, absence of the fibula, anterior bowing of the tibia, talipes equinovalgus, and anomalies of the tarsal and metatarsal bones are the typical components of this anomaly. When the fibrous band was sought in a typical patient, it was found. When this band was removed, partial or complete correction of each element of the deformity, except for limb-length discrepancy, was effected. In the older patients, in whom the band was not excised, the tibial bowing persisted, and for correction, required tibial osteotomy.

There were no stigmata of neurofibromatosis, except an occasional *café-au-lait* mark. No fractures occurred and all of the tibial osteotomies healed promptly. We considered the tibial bowing an entirely different condition from congenital pseudarthrosis of the tibia. The cortical sclerosis at the site of maximum tibial bowing can be explained on a mechanical basis, since following correction of the bow, the sclerosis lessens. It seems reasonable to assume that the bow-string action of the tight band is contributory to the tibial deformity and the talipes equinovalgus of the foot. How much this contributes to limb shortening cannot be determined. We believe that treatment should include excision of the tight band and release of any other tight soft-tissue structure in the calf at the earliest possible age. As in congenital torticollis, the elimination of a deforming factor is most effective when accomplished early. In our series we believe that excision of the band allowed better positioning of the foot, permitted a more normal gait, and has made a Syme's amputation possible if indicated at a later date.

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DISCUSSION

Dr. John J. Fahey, Chicago, Illinois: This is one of the most significant studies made on this relatively rare condition which presents many problems in treatment. The authors have given the first accurate anatomical description of the fibrous band and have emphasized its clinical significance. The band, no doubt, has been released by other surgeons performing soft-tissue release of the posterior and lateral structures of the ankle, but only in a few instances has it been recognized as a definite structure. There is still controversy over the part that the fibrous band plays in producing the bowing deformity of the tibia. Comparing the

authors' young patients with those that are seen late and those that reach adult life without treatment, one is convinced that either the fibrous band or other soft tissues influence the prevention of spontaneous correction of the bowed tibia. The bowing associated with congenital posterior angulation of the tibia can be corrected spontaneously with proper bracing. Following osteotomy for correction of the bowing of congenital absence of the fibula, the fracture site heals normally in contrast to congenital pseudarthrosis.

One might wonder why amputation is not carried out more frequently since the limb-length discrepancy is great even with treatment—five inches or more when growth is completed, as shown by the authors. However, many of these patients in the earlier years of growth have a good foot, and the discrepancy is not great enough to preclude good function with a special shoe or a brace. In instances when the limb-length discrepancy is gross in the young patient and in most patients during the latter few years of growth, it is difficult to determine whether amputation should be postponed. This problem, however, seemed no major factor in the authors' cases. They have shown the value of preserving the lower tibial epiphysis and performing a Syme's amputation when growth is completed, thus avoiding possible revision of the stump and securing a more suitable limb for the fitting of a prosthesis. Rarely is the discrepancy so great and the deformity of the foot so pronounced that amputation is recommended earlier in life.

Dr. Halford Hallock, New York, N. Y.: The authors have presented a careful study of a group of patients with congenital absence of the fibula, an uncommon anomaly, the treatment of which is usually difficult and often unrewarding.

The outstanding contribution of this study is the demonstration of the frequent existence of the fibrous band, its significance to pathogenesis of the deformity, and to the correction achieved, when it is excised. The results in at least six young patients, in whom only excision of the band was performed, testify to this and are of great interest and are encouraging.

This does not imply, however, that there will be no need for other surgical procedures. A fibrous band may not be found in every case; none was mentioned in the records of the nine patients with congenital absence of the fibula at the New York Orthopaedic Hospital in the past twenty-five years, although it is quite possible that such a band may have been overlooked. Osteotomies, capsulotomies, lengthenings and transfers of tendons will still be necessary in some patients to correct deformity and to stabilize the tarsal bones when it is possible thereby to obtain a functioning extremity. Unfortunately, the frequently great degree of limb shortening will defeat the purpose of stabilization, and will necessitate in many instances, eventual amputation to completely resolve the combined problems of deformity, instability, and gross inequality of limb length.

But these considerations, important as they are, need not detract from the value and logic of early excision of a deforming fibrous band which has been demonstrated by the authors to be so efficacious in itself in overcoming deformity and maintaining functional position, until further measures may or may not be indicated.

Compression of the Bone Ends as an Aid to Union in Fractures

A Report on Forty-nine Ununited and Four Recent Fractures *

BY THOMAS KING, M.D., F.R.C.S., MELBOURNE, AUSTRALIA

This is the record of a method in which about twenty-five pounds of pressure was exerted on the bone ends at the fracture site, together with observations on the frequency and rapidity of bone union. This use of pressure was adjunctive to external or internal splinting or both.

There is confusion on the subject of mechanical influences and their manner of

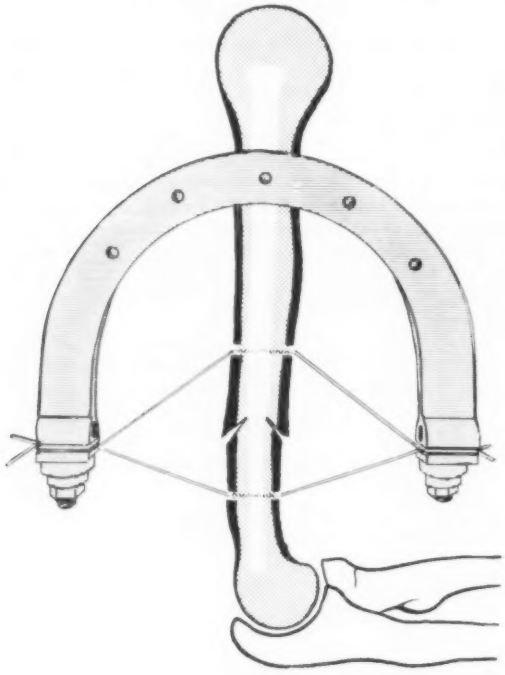

FIG. 1

Greifensteiner's method of compression with two stretched Kirschner wires. Note how countersinking engages the two cancellous bone surfaces.

affecting osteogenesis. This especially applies to the question of pressure or compression. Charnley[3,4] believed that compression was effective only on cancellous bone and was not a suitable method for fractures since compact bone was largely involved. Figures 1 and 2 show the method of effecting compression that I use; compression acts largely on the cancellous bone of the shafts. Admittedly this surface area of cancellous bone is a good deal smaller than that which is compressed in arthrodesis of the knee or ankle joints. Some

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1957.

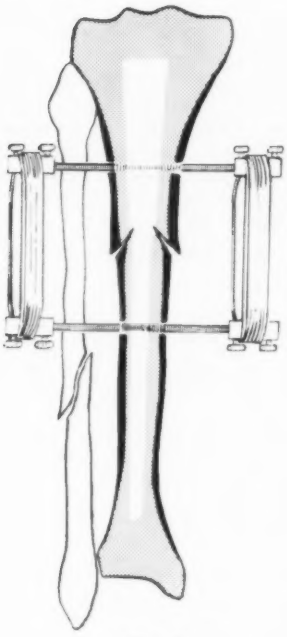

FIG. 2

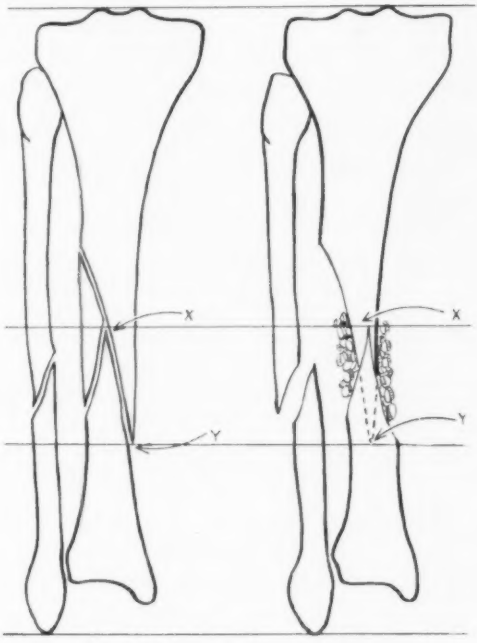

FIG. 3

FIG. 4

Fig. 2: Compression with Steinmann pins and heavy rubber bands. When the pins just begin to bend, there is a pressure force of about twenty-five pounds.

Fig. 3: An ununited comminuted fracture of the tibia. There is no shortening, as shown by the two parallel lines passing through the distal (*X*) and proximal (*Y*) ends of the main fragments.

FIG. 4: Shortening has been avoided by thrusting the pointed proximal end (*Y*) into the medullary cavity of the distal fragment. The comminuted fragment has been excised and ground up in the bone mill and then packed around the fracture site. If compression is now used there will be no shortening.

authorities, for example, Volkmann, claimed that severe pressure prevented bone formation and caused resorption; but Wolff, so often quoted, supported the opposite view. Again, according to other authorities[8,15], continuous pressure favored resorption. However, according to Jores, if it was intermittent and at long intervals, there was bone proliferation at the site of pressure, but, if the intervals were short, corresponding to those in an aneurysm, the pressure acted as if it were continuous. These various views can be considered only with reserve; there are too many other variables about which we know so little.

There I am prepared to leave theoretical matters and confine myself to clinical observations. When fractures of the tibia were treated in "walking casts" delayed union and non-union were only too common. The object was to obtain the stimulus of compression on the bone ends, according to the Wolff doctrine, because this was considered beneficial in promoting new bone profusely and quickly. Unfortunately, a torsion force on the fractured bone ends which counteracted any possible benefit from the compression at the transverse fracture site was created when the patient walked. The patient would plant the walking iron firmly on the ground and, especially if nimble, pivot forward with a twist of the whole body that included the tibia proximal to the fracture.

The first important clinical application of pressure began with Key's[10,11] original method of compression arthrodesis of the cancellous bone of the tibia and femur at the knee joint. This has been convincingly supported by Charnley[2]. The method is being widely used with apparent satisfaction and few unfavorable reports. Eggers, Shindler, and Pomerat carried out experimental work on the union of fractures caused by saw cuts

TABLE I

COMPRESSION FOR UNUNITED FRACTURES

Case	Age	History	Date of Operation and Compression	Date of Clinical and Roentgenographic Evidence of Bone Union	Required Time for Bone Union (*Days*)
1	56	Ununited fracture of the lower end of the humerus; bone graft and Parham band 25 years ago	9–3–52	11–30–52	89
2	45	Compound fracture of the lower end of the humerus, 5–30–52; sinus 8–6–52	9–6–52	12–15–52	101
3	73	Fracture of the tibia and fibula primarily plated elsewhere 1 year previously	9–10–52	12–18–52	101
4	24	Compound fracture of the lower end of the humerus in 1950; plated elsewhere; sinus 8–6–52	9–25–52	11–25–52	62
5	35	Compound fracture of the lower end of the humerus, 4–26–52; sinus	10–6–52	1–24–53	110
6	33	Monteggia's fracture; compound fracture of the ulna, 9–7–52	10–13–52	1–10–53	59
7	19	Compound fracture of the humeral shaft, 7–14–52	10–20–52	4–30–53	163
8	31	Compound fracture of the tibia and fibula, 7–12–52	10–20–52	5–29–53	192
9	56	Oblique fracture of the tibia and fibula, 9–8–52	10–22–52	1–22–53	183
10	64	Non-union of the radius and ulna for 4½ months	10–29–52	4–14–53	185
11	64	Same as No. 10; radius and ulna	10–29–52	Ulna: non-union	
12	38	Compound fracture of the tibia and fibula, 6–27–52; sinus	11–10–52 (Compression without open operation)	2–14–53	95
13	37	Fracture of the shaft of the radius, 8–12–52	12–15–52	Non-union	
14	37	Same as No. 13	Second operation	Non-union	
15	31	Fracture of the shaft of the radius, 2–1–52	12–17–52	2–2–53	74
16	31	Same as No. 15; ulna shortened	10–10–53	Non-union of ulna	
17	38	Fracture of the radius of some months' duration	1–5–53	3–12–53	68
18	23	Gunshot fracture of the tibia and fibula, 3–15–49; sinus	1–5–53	7–3–53	181
19	35	Compound fracture of the humerus, 10–12–52; sinus	1–28–53	5–27–53	125
20	35	Same as No. 19; compound fracture of the radius, 10–12–52	1–28–53	5–27–53	125
21	35	Same as No. 19; compound fracture of the ulna, 10–12–52; sinus	1–28–53	5–27–53	125

TABLE I (*continued*)

COMPRESSION FOR UNUNITED FRACTURES

Case	Age	History	Date of Operation and Compression	Date of Clinical and Roentgenographic Evidence of Bone Union	Required Time for Bone Union (*Days*)
22	75	Compound fracture of the tibia and fibula, 6–9–52; sinus 3–11–53	3–11–53	6–24–53	106
23	26	Compound fracture of the tibia and fibula of three years' duration	3–23–53	5–23–53	61
24	55	Fracture of the tibia and fibula, 11–9–52	3–25–53	7–24–53	122
25	27	Compound fracture of the tibia and fibula, 1947; several operations; sinus	5–27–53	7–27–53	62
26	43	Fracture of the ulna, 5–5–52	7–1–53	10–23–53	115
27	44	Compound fracture of the femur, 5–15–53	7–5–53	8–26–53	53
28	44	Compound fracture of the radius and ulna, 12–16–52	7–5–53	11–12–53	131
29	44	Same as No. 28	7–5–53	11–12–53	131
30	55	Compound fracture of the tibia and fibula of three months' duration	7–10–53	Non-union	
31	50	Fracture of the humerus of one year's duration	7–13–53	Non-union	
32	23	Compound fracture of the tibia and fibula, 3–1–53	7–14–53	1–18–54	188
33	40	Fracture of the femur, 3–3–53	7–27–53	10–30–53	96
34	20	Fracture of the radius, 4–6–52	7–27–53	10–20–53	87
35	20	Same as No. 34; fracture of the ulna	7–27–53	11–23–53	121
36	44	Compound fracture of the tibia and fibula, September 1950; sinus	8–19–53	Non-union	
37	47	Compound fracture of the tibia and fibula, 7–29–53	8–19–53	11–17–53	98
38	33	Fracture of the tibia and fibula, 9–18–52	8–26–53	1–18–54	146
39	19	Gunshot fracture of the humerus, 1950; sinus	9–7–53	10–21–53	45
40	16	Compound fracture of the tibia and fibula 5–16–52	9–30–53	11–25–53	56
41	40	Fracture of the femur, 6–11–53	10–28–53	2–18–54	114
42	66	Compound fracture of the tibia and fibula, August 1952; chronic osteomyelitis	11–4–53	3–2–54	120
43	24	Compound fracture of the radius, 11–25–51	12–7–54	1–20–55	44
44	24	Compound fracture of the ulna; same as No. 43	12–7–54	1–20–55	44
45	48	Compound fracture of the humerus, 12–25–53	2–22–54	Non-union	
46	61	Fracture of the humerus, 8–28–52	2–22–54	4–29–54	59
47	29	Fracture of the tibia and fibula, 5–23–56	7–10–56	11–20–56	135
48	50	Fracture of the humerus, 6–7–56	7–25–56	9–24–56	60
49	67	Compound fracture of the tibia and fibula, 5–3–56; sinus	10–15–56	12–23–56	68

FIG. 5-A

FIG. 5-B

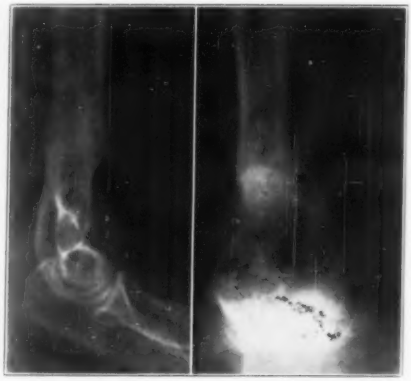

FIG. 5-C

Fig. 5-A: Case 4. Compound fracture of the humerus that had been plated in 1950. The plate had to be removed and a sinus persisted until a few weeks before the compression operation.

Fig. 5-B: The fracture was compressed for nearly seven weeks (which was too long) by the two stretched Kirschner wires. Angulation was avoided by the use of the two intramedullary rods inserted from near the lateral epicondyle of the humerus.

Fig. 5-C: One year later there was strong union. No sinus was present and there were normal movements at the elbow joint. The fracture had united in nine weeks.

in the skulls (cortical bone) of rats, in order to determine the influence of a compressing force in osseous repair. They called this force the contact-compression factor. They believed that this factor favored osteogenesis and union of fractures, although they mentioned that excessive pressure caused necrosis of the compressed bone. Charnley [4] was skeptical about the favorable effect of compressing the cortical bone ends in a fracture because new-bone formation in shaft fractures was attributed largely to external periosteal callus. This observation may not be valid. For example, in the case of long oblique fractures of the tibia, bone union appears to be favorably influenced, according to some surgeons[14, 16], by one or two screws that compress the surfaces together. In this oblique type of fracture, the formation of periosteal callus is usually slight or absent. Admittedly, on account of the obliquity of the fracture, the compression is acting on a large area of cancellous tibial bone. Regarding the formation of so-called medullary callus in this instance, compression can hardly be invoked as a favorable agent because marrow is osteolytic and has a tendency to cause erosion, resulting in an increase of the medullary cavity as is often seen [12]. If there is such a thing as medullary callus, it can hardly develop when a Küntscher nail is used in the femur, especially if the fracture is in the vicinity of the isthmus, or narrowest diameter of the medullary cavity, which is then completely occupied by the nail (Figs. 7-A through 7-D).

In 1952, Lorenz Böhler of Vienna showed me an example of successful bone union obtained by compression of an ununited fracture by means of Greifensteiner's method [6, 7] when sinuses and infection were present. Böhler said that he had treated many such fractures with success, and his surgical staff spoke with enthusiasm of the method. As a result, I felt justified in trying it, especially for non-union of the shafts of long bones when infection was present, because operation was usually denied these patients, if for no other reason than that bone-grafting was not justifiable. Sometimes even amputation is considered in such cases.

TECHNIQUE

The fractures may be transverse, comminuted, or oblique. In transverse fractures, the object is to avoid engaging the dense cortical bone at the pressure surfaces (Figs. 1 and 2). The bone end with the larger diameter is reamed or countersunk and the medullary

cavity is opened up by a drill or gouge. The end with the smaller diameter is sharpened or pointed and again the medullary cavity is opened up by a drill. As a result, the surfaces in contact, especially in the upper end of the tibia and in the supracondylar region of the humerus, consist almost entirely of cancellous bone. The operation should be performed with a conservative exposure, thereby avoiding any unnecessary disturbance to the blood supply of the bone. A tourniquet is not applied; it is essential to see that the two bone ends should bleed. Bone chips from the ilium are unnecessary, but bone derived from the shaping of the countersunk bone end is run through a bone mill and packed around the fracture site. Several $^{9}/_{64}$ of an inch drill holes are made in the bone near the fracture site in order to promote revascularization.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 39. Gunshot wound and compound fracture of the humerus. The radial nerve was severed.

Fig. 6-B: Roentgenogram showing non-union after fourteen months. The tendon transplantations to correct the radial-nerve paralysis were successful. A small sinus was still present at the fracture site.

FIG. 6-C

FIG. 6-D

Fig. 6-C: In this case, pointing and countersinking the bone ends would have caused too much shortening of the limb. The two fractured surfaces were compressed after a conservative freshening. The rod prevents angulation. This operation was performed September 7, 1953.

Fig. 6-D: In January 1954 the fracture was united and was clinically firm. The sinus had healed.

In oblique and comminuted fractures, the countersinking of one fragment into the other would result in too much shortening of the limb. However, the same principle is used as that in transverse fractures in order to avoid the compression force causing shortening; a pointed end is engaged into the medullary cavity of the other fragment. In this way, at least one cancellous surface is in contact (Figs. 3 and 4).

FRACTURED BONES SUITABLE FOR COMPRESSION

1. *Lower End of the Humerus*

This is very suitable as it is a common site for non-union and infection. If compression is nothing else, it is an excellent method of immobilization, especially if there is a tendency

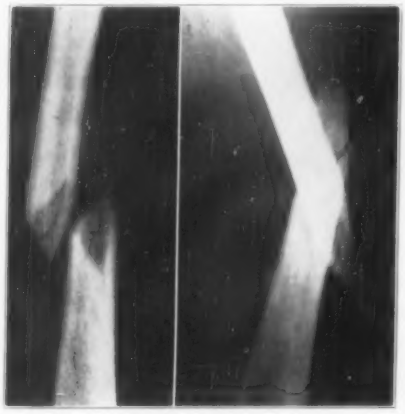

FIG. 7-A

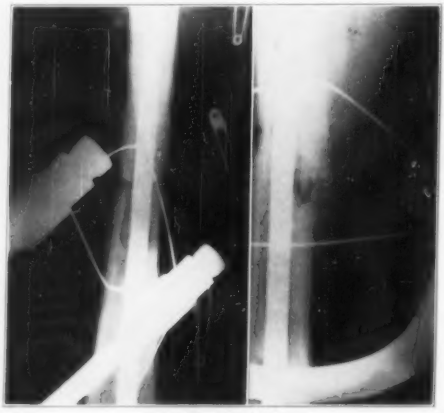

FIG. 7-B

Fig. 7-A: Case 41. Roentgenogram showing compound fracture of the femur then four months old. There was no sinus.

Fig. 7-B: Operation was performed on October 28, 1953. A step cut was made in order to avoid shortening of the limb and to have some cancellous bone compressed.

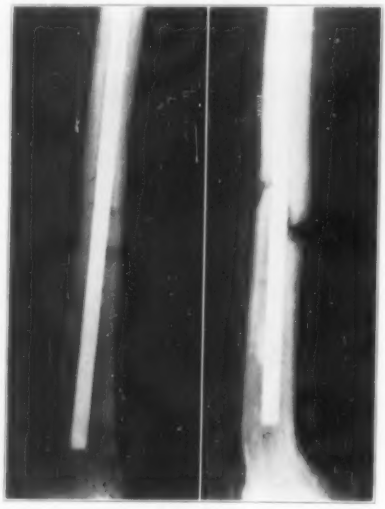

FIG. 7-C

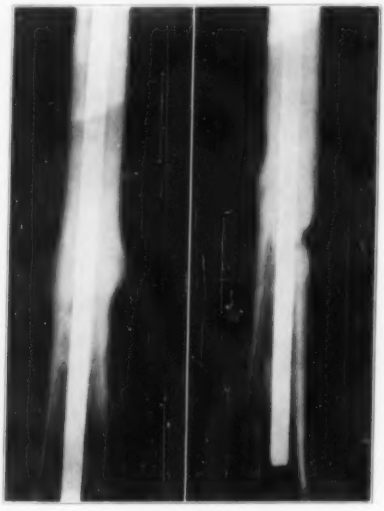

FIG. 7-D

Fig. 7-C: Union was not complete after four months. Note the absence of any periosteal callus or new bone.

Fig. 7-D: Bone union was complete on January 13, 1955, and the nail was removed. There was some anterior periosteal new-bone formation.

TABLE II

COMPRESSION FOR THIRTEEN UNUNITED FRACTURES WITH SINUSES

Bone	Number	Bone Union	Non-Union	Average Time for Union (*Weeks*)
Humerus	5	5		12½
Ulna	1	1		18
Tibia	7	6	1	16
	13	12 (92%)	1 (8%)	

to resorption of the bone ends after operation. The proximal end is pointed and countersunk into the lower end. The tendency to angulation when compression is applied can be avoided by introducing one or two intramedullary $^3/_{32}$ of an inch rods just proximal to the coronoid fossa and from the lateral side of the humerus (Fig. 5-B), *before* insertion, with an electric drill, of the two Kirschner wires used for the compression. Thereafter, the speed of the Kirschner wires in the drill deflects their pointed ends from the intramedullary rods.

2. *Radius and Ulna*

I no longer use compression for fractures of these bones, as unequal shortening of the bones has resulted in subluxation of the distal radio-ulnar joint.

3. *Femoral Shaft*

The femoral shaft is not very suitable bone for compression because there is not much cancellous bone to compress except in the lower end of the shaft (Figs. 7-A through 7-D). Use of the Küntscher nail is essential in order to avoid angulation; this introduces danger if infection is present. The ideal site for the Küntscher nail is the middle of the shaft where the medullary cavity is narrowest and therefore grips the nail firmly. Unfortunately the bone is compact at this site (Fig. 7-C).

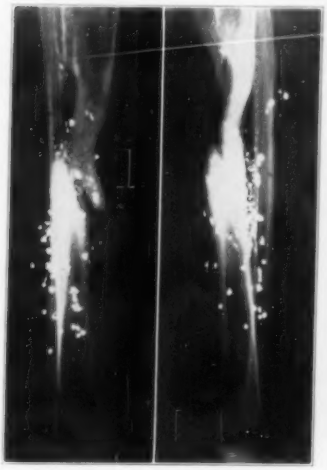

FIG. 8-A

FIG. 8-B

FIG. 8-C

Fig. 8-A: Case 18. Roentgenogram showing effects of a shotgun injury three and one-half years previously. There were non-union and a sinus.

Fig. 8-B: Roentgenogram made January 5, 1953, after the fractured bone ends were countersunk. The fibula had been broken.

Fig. 8-C: The fracture united in 181 days. Roentgenogram made November 14, 1956, nearly three years later, shows solid union. The sinus was healed.

4. *Tibia*

The ideal location is in the upper half of the shaft where there is cancellous bone. If the fracture is transverse, the lower pointed end is countersunk into the upper (Fig. 2). The fibula must be refractured. Internal fixation with Eggers plates may be sometimes used but is better avoided in order to conserve the blood supply to the bone ends by a conservative exposure.

FIG. 9-A

METHOD OF COMPRESSION

1. *Greifensteiner's Method*

This method, with two Kirschner wires stretched in a stirrup, is useful in the upper extremities where important vessels and nerves must be avoided. In the lower extremities it is necessary either to have wide stirrups or to weld a length of steel in the bow.

The hole in the wire stretcher should be large enough to hold two Kirschner wires. Before drilling the two fragments about two inches from the fracture site and on either side the wound should be temporarily closed by two towel clips. Otherwise it would not be possible to close the wound later on account of the wires lying in it instead of piercing the skin. The wires are stretched in the stirrup until they are taut and when tapped produce a "ting;" there is only slight movement when the bone fragments are rocked. By experiment and measurement it has been found that

FIG. 9-B

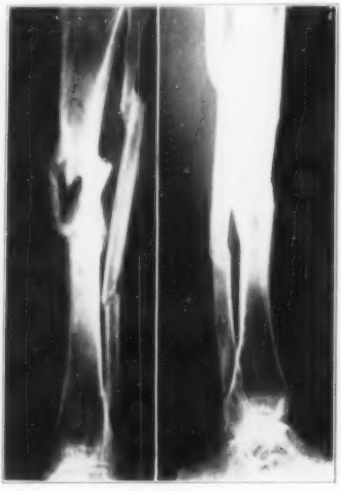

FIG. 9-C

Fig. 9-A: Case 12. The patient had a compound fracture of the tibia on June 27, 1952. Roentgenogram made October 22, 1952, showed that there was non-union and that a sinus was present.

Fig. 9-B: No operation on the fracture was performed since it would have resulted in too much shortening of the limb. Only compression by means of rubber bands and pins was used.

Fig. 9-C: The bone was clinically firm in ninety-five days. This roentgenogram was made on July 3, 1953, eight months after operation. The sinus had healed.

TABLE III

COMPRESSION FOR RECENT FRACTURES

Case	Age	History	Date of Operation and Compression	Date of Clinical and Roentgenographic Evidence of Bone Union	Required Time for Bone Union (*Days*)
1	43	Fracture of the tibia and fibula, 9–30–52	10–8–52 (With Eggers plate)	1–15–53	110
2	39	Oblique fracture of the tibia and fibula, 10–26–52	11–26–52 (With Eggers plate)	1–30–53	66
3	19	Compound fracture of the tibia and fibula, 11–7–52	12–3–52 (With Eggers plate)	4–15–53	151
4	64	Compound fracture of the tibia and fibula, 9–28–56	10–21–56	12–23–56	62

the tension of the wires maintains this position when there is a pressure of about twenty-five pounds.

2. *Steinmann Pins and Rubber Bands*

If a nail eight inches by $^3/_{16}$ of an inch is clamped at one end in a vice and the other end is connected by a heavy rubber band to a spring scale, the nail just begins to bend when the scale reads about twenty-five pounds. The nail should be drilled (and never hammered) into the bone at least two inches from the fracture site, and through the skin after temporary closure of the wound. Caps on the nail ends prevent the rubber bands from slipping and causing pressure on the skin (Fig. 2).

IMMOBILIZATION

Wool padding is used to cover the pins or stirrups and the whole limb. This padded cast is removed together with the pins or wires after from four to six weeks. A new and unpadded cast is then applied.

The period of compression is four weeks for the humerus, from four to six weeks for the tibia and six weeks for the femur.

SUMMARY

Forty-nine ununited fractures were compressed after the bone ends had been countersunk by open operation, with one exception. This patient, Case 12 (Figs. 9-A through 9-C), had compression alone, without exposure of the bone ends, and bone union resulted. Forty-one fractures (83.7 per cent), united. Twelve of the thirteen with sinuses before operation united. When the fractures united, the sinuses healed. Four recent fractures with gross displacement united.

CONCLUSIONS

1. Compression does not appear to shorten the period required for bone union. This raises the question: "Does compression have a more favorable effect on bone union of fractures than does absolute immobilization for from four to six weeks?" At the end of that time there appeared to be less movement at a few of the fracture sites than was usual, but in most the degree of mobility did not appear to be greater or less than that in those fractures treated without compression.

2. The real value and place for compression is in the treatment of infected and ununited fractures, especially those in the lower third of the humerus and in the upper half of the tibia. Apparently it is the greater amount of cancellous bone there which favorably affects the results of compression.

3. Although no special complications arose in connection with the transfixion pins and wires, it does not appear advisable to use them in recent fractures for compression, especially if the fracture is near a joint.

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Congenital Anomalies of the Hand

Part II*

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In Part I, in the section on the management of confluent digits, we stressed the value of pedicled skin grafts in the surgical reconstruction of hands with multiple and complex deformities. At this point, before discussing the more intricate surgical procedures, it would seem appropriate to mention a few points concerning these grafts, without which it would not have been possible either to treat some of the deformities seen in our practice or to obtain some of the good results which were achieved.

Pedicled Skin Grafts

There are two main types of pedicled grafts, the *tube* and the *flap*. In the tube, the cut edges are sutured together to hide the areolar interior, while in the flap the undersurface is either lined with a split-thickness skin graft or left uncovered. A small ovoid segment cut from an unlined flap is called a *petal-flap*, while a similar segment with a short tube as a stalk is called a *stemmed-petal*.

The abdomen is considered the most convenient site for the elevation of grafts which are to be attached to the hand. In the interest of comfort, the opposite side of the abdomen from the involved hand is selected. The donor site should be a region in which hair will not grow later, for the degree to which hair will be grown in an individual cannot be anticipated in childhood with any degree of certainty. Inspection of the abdomen of the parents may be of some help in determining this, and racial heritage is another factor. The sex of the child also must be considered: in males the outer portion of the upper quadrants of the abdomen are less likely to be hairy, while in the female the lateral segments of both upper and lower quadrants can usually be used with safety. Motility tests of the skin of either upper quadrant have shown that the fold which can be formed most easily slants from the outer border medially and distally—following the same general course as the lower intercostal and lateral lumbar arteries. Since it is thus apparent that the lines of tension in this area are parallel to the segmental vessels, it would seem that more resilient and viable skin could be obtained if the incisions outlining the pedicle graft were also made parallel to the segmental vessels. In outlining the graft, the starting point of the proximal incision should be medial to that of the distal incision and the finishing point should be correspondingly closer to the mid-line. If the ends of the incisions were to be joined, the resulting outline would resemble a parallelogram, and since the connecting lines in a parallelogram are longer than those of a rectangle, the portion of the graft placed across the pathway of the segmental arteries is thus broader than it would be otherwise. In order to obtain better nourishment of the graft, the space between the two incisions should be wide, that is, it should be more than one-third the length of the incisions.

The small petal-flap can be connected to the hand immediately, but the longer stemmed-petal cannot be attached until five or six days after the medial pedicle has been detached from the abdomen. It is necessary to wait until the stem has closed in on itself in order to see how much of it will slough off; the surviving portion is sutured to the hand. With the larger tubes or flaps, it is necessary to wait even longer—two to four weeks—before detaching the medial pedicle from the abdomen and suturing it to the hand. The lateral pedicle of the graft is left attached to the abdomen for as long as seven weeks before

*Congenital Anomalies of the Hand, Part I, appeared in the October 1957 issue of The Journal, pp. 1002-1019.

Fig. 1-B

Fig. 1-D

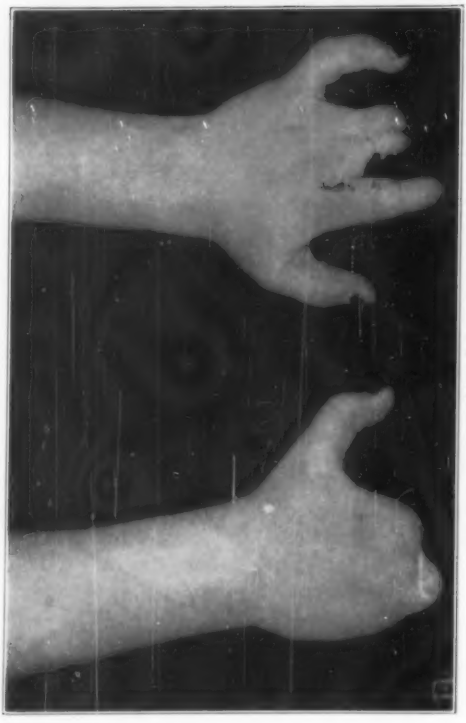

Fig. 1-A

Fig. 1-C

Figs. 1-A through 1-F: Deepening of the intermetacarpal cleft in a four-year-old girl with bilateral congenital anomalies.

Figs. 1-A and 1-B: Preoperative photographs.

Fig. 1-C: Roentgenogram of both hands.

Fig. 1-D: Photograph showing the two hands corrected by a tube graft which was originally lifted from the abdomen.

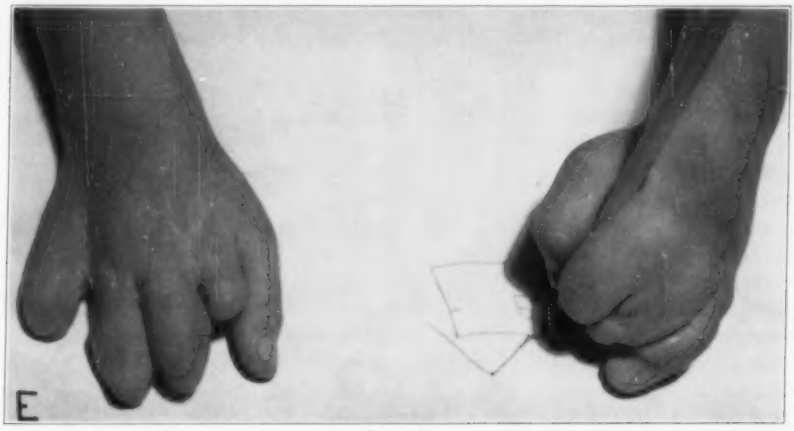

FIG. 1-E

FIG. 1-F

Photographs showing the results following surgery.

it is separated from its original source of nourishment. In patients with bilateral deformities, the graft is first attached to the opposite hand and then, seven weeks after the separation of the lateral pedicle, the tube of skin is divided and portioned between the two hands.

Unless a small flap is simultaneously raised to cover a commensurate surgical defect, other reconstructive work is not initiated until at least a month after the skin supplied by the pedicle graft has been flattened, the suture lines have healed, and seepage has discontinued.

Mobilization of Metacarpal Bones

Of the five metacarpal bones, the first has the greatest range of motility and the fifth

has the next greatest range. The fourth can also be made to move to some degree, but the second can be made to move only slightly and the third cannot be made to move at all. If the first, fifth, and fourth metacarpals are separated from their neighbors and covered with skin, they will function as short stubby fingers. In hands in which this has been done, the third metacarpal is also wrapped with skin, for although it cannot be made to move, it can be used as an appositional strut. If the second metacarpal bone is resected, the web space between the first and third metacarpals will be widened, which will increase the relative length of the separated rays on the radial side of the hand. Excision of the second metacarpal provides enough skin to cover the entire first metacarpal as well as the radial surface of the third metacarpal. Skin from the dorsum of the fourth metacarpal ray is used to cover the fifth metacarpal, and the resulting denuded area is lined with skin from a pedicled graft previously raised on the abdomen.

In order to separate the four ulnar metacarpals, the webs between them are deepened, the transverse metacarpal ligament being severed in the process (Figs. 1-A through 1-F). The clefts thus created may extend for two-thirds the length of each metacarpal, the first and fourth intermetacarpal spaces being deeper than the others. The uncovered surfaces of the surgically deepened web spaces are lined partially with integument obtained locally, but mainly with skin supplied by the pedicled graft. Since the skin of the pedicled graft is devoid of sensation, it should not be used to cover the volar surfaces. The palmar skin overlying the metacarpal bones is left intact, and the transplanted skin is used to cover defects in the web spaces and also to cover the adjacent and dorsal surfaces of the metacarpal rays.

Transfer of the Index Finger to Take the Place of the Missing Thumb

The thumb is considered to be the most useful digit. Without it the hand is deprived of many of its functions (Figs. 2-A through 2-D). The palm can still be used as a paddle, the remaining fingers may serve as hooks and may hold objects by means of the weaker side-to-side pinch; but the more effective pulp-to-pulp pinch is lost, the hand as a whole has no power of grip, and torsional grasp in which the thumb and the bones linking it to the wrist serve as extensions of the pronating and supinating wrist is weakened if not completely destroyed.

Since Nicoladoni first published his work on the transference of a toe to take the place of a missing thumb, this procedure has been periodically revived. From time to time various other surgical ventures have also been proposed, including attaching a tube graft in the location of the missing thumb and giving it rigidity by inserting a remodeled rod of bone. In our opinion these manifestations of surgical virtuosity should be dismissed entirely, for whatever is put in place of the thumb must be able to feel and move—there must be sensory pathways to the brain and muscles which will register motor responses.

When judiciously shifted radialward and turned to face the other digits, the index finger, which is equipped with sensory nerves, blood vessels, tendons, and muscles, may serve as a physiological substitute for the missing thumb. Use of this finger as a substitute has advantages, for it has one more joint than the thumb and its intrinsic muscles—the interossei and especially the lumbricales—can effect skilled movements. This does not mean that a substituted index finger is to be preferred to a normal thumb, however. Because of its bulky thenar muscles, the thumb is more powerful than the index finger and thus what is gained in agility by the substitution is lost in power. Furthermore, the hand loses the index finger. Nevertheless, the substitution is fully justified, for while there is very little that the index finger can do which the adjacent long finger cannot do, there is no finger which can do what the thumb does. In short, the usefulness of the hand is enhanced by the restoration of some of the functions of the thumb.

During the Second World War we used this technique to treat battle injuries, with gratifying results. Treating war injuries is considerably more difficult than treating

FIG. 2-A

FIG. 2-B

FIG. 2-C

FIG. 2-D

The functioning of a hand without a thumb. The hand can be used as a hook (*A*); can grasp weakly (*B*); can clutch a doorknob but cannot turn it effectively (*C*); and can wield a pencil, but by means of the awkward side-to-side pinch rather than pulp-to-pulp pinch (*D*).

congenital deformities, for in a war injury absence of the thumb is often associated with complicating factors: for example, the index finger may have been shattered at the same time as the thumb was shot off or its tendons may have been severed and its blood supply damaged; also open wounds and infections may be present. In a hand with congenital absence of the thumb, the tendons, nerves, and blood vessels of the index finger are intact; the base of the metacarpal is not blocked on the radial side, so that the bone can be pushed into the desired position of abduction; and the metacarpal is not shattered, so that derotation osteotomy can be performed at the desired level. Furthermore, the patient is young and the tissues are more yielding, with the result that the operation can be performed with greater ease and a better chance of success, in a much shorter time and with fewer steps. The treatment of war injuries often requires numerous operations spread over as long as seven months, while the treatment of congenital deformities may be completed in three months with two operations.

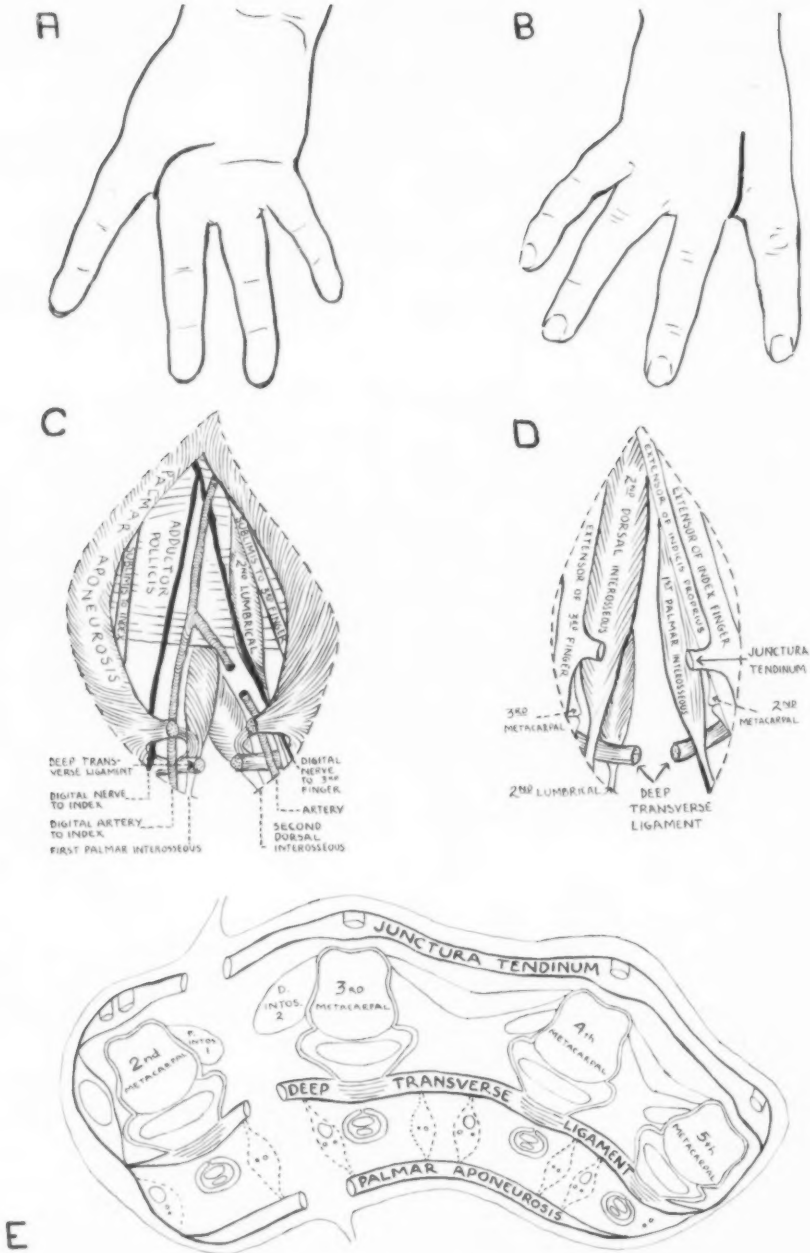

FIG. 3. *A* through *E*

Fig. 3: Transference of the index finger to replace the missing thumb. *A*. Volar incision. *B*. Dorsal incision. *C*. Volar view of the intermetacarpal cleft: the digital artery which will be located along the radial aspect of the long finger has been cut beyond the bifurcation of the common trunk; the artery to the index finger has not been interfered with; the interlacing fibers of the palmar aponeurosis and the deep transverse metacarpal ligament have been severed. *D*. Dorsal view of the intermetacarpal cleft: the junctura tendinum and the transverse metacarpal ligament have been cut, and the radial head of the bicipital second dorsal interosseus has been stripped away from its origin on the index metacarpal. *E*. Cross section through the distal portion of the palm showing the deepened and widened intermetacarpal cleft, and the three strong bands that had to be cut: the junctura tendinum, the transverse metacarpal ligament, and the transverse interlacing fibers of the palmar aponeurosis.

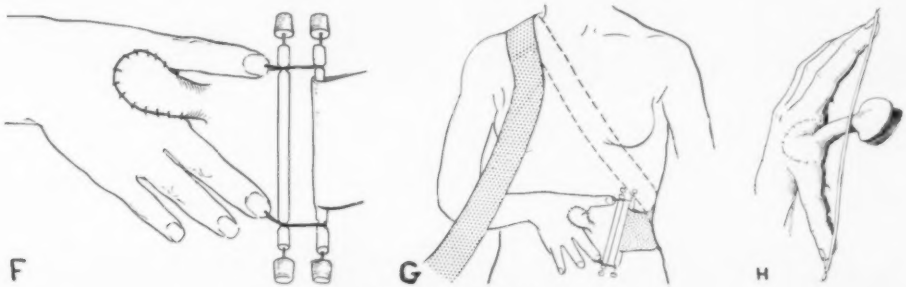

FIG. 3, *F* through *H*

Transference of the index finger to take the place of the missing thumb. *F*. The pedicled abdominal graft has been sutured to the widened intermetacarpal graft and the spreader splint has been attached to the fingernails. *G*. The start of the Velpeau bandage. *H*. Weaning of the nourishing end of the pedicled graft from the abdomen. In patients with bilateral deformities, this end may be used to line the surgically widened interdigital cleft of the opposite hand.

In substitution of the index finger for a missing thumb (Figs. 3 through 4-M), the first operation consists in deepening and widening of the web space between the index and long fingers and covering of the resulting cleft by a graft containing areolar tissue. At the same operative session, the pedicled graft is lifted from the abdomen and the web space between the index and long fingers is opened, adequate pneumatic constriction of the arm being maintained. The skin incision may be started on the palm or dorsum of the hand. The volar incision is begun just proximal to the distal palmar crease at a point which is in line with the central axis of the long finger. It is extended radialward parallel to the palmar crease and is then turned distally so that it bisects the web between the index and long fingers. Following this it is continued dorsalward in the cleft between the second and third metacarpals and is ended at a point an inch or more proximal to the interdigital web. The connected dorsal and palmar incisions sever three binding structures: the junctura tendinum that connects the extensor tendons of the index and long fingers, the interlacing fibers of the palmar aponeurosis, and the transverse metacarpal ligament which binds the heads of the two metacarpals. Distal to the bifurcation of the common arterial trunk, the digital artery along the radial side of the long finger is ligated in two places and is then severed between the two ligatures. The branches of the median nerve supplying the adjacent surfaces of the index and long fingers need not be disturbed since they separate from the main trunk more proximally. If the adductor pollicis is present, the distal fibers of its transverse head are stripped from the third metacarpal in order to deepen the surgical cleft behind the median nerve. The dissection is then carried deeper into the palm toward the wrist—along the interspace between the volar interosseus of the index finger and the dorsal interosseus on the radial side of the long finger. (The volar interosseus of the index finger arises by a single head from the second metacarpal. The dorsal interosseus on the radial side of the long finger is bicipital; it arises from two heads on the adjacent surfaces of the second and third metacarpals. Unless its attachment to the second metacarpal is released, it will not permit this bone to be abducted radially.) The index finger is now abducted radially as far as possible, the pneumatic constrictor

FIG. 4-A

FIG. 4-B

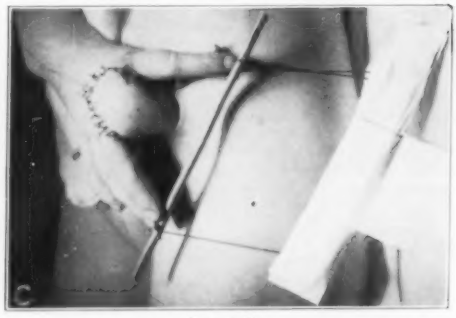

FIG. 4-C

Figs. 4-A through 4-P. Shifting of the index finger in an older child (a five-year-old girl) with congenital absence of the right thumb.

Figs. 4-A and 4-B: Volar and dorsal views of the hand.

Fig. 4-C: The pedicled graft has been sutured to the surgically deepened and widened intermetacarpal cleft between the index and long fingers. The fingers are held in position by the spreader splint, to which has been attached one end of the Velpeau bandage.

FIG. 4-D

FIG. 4-E

FIG. 4-F

Application of the Velpeau bandage

FIG. 4-G

FIG. 4-H

FIG. 4-I

FIG. 4-J

FIG. 4-K

FIG. 4-L

FIG. 4-M

Figs. 4-J and 4-K: Volar and dorsal views of the hand following abduction of the index finger.
Fig. 4-L: Following derotation osteotomy of the second metacarpal, a Kirschner wire was passed through the distal phalanx of the index finger and hooked to a rotatory splint attached to a cast on the arm.
Fig. 4-M: When the desired degree of rotation had been obtained, the abducted index finger was placed in a cast.

FIG. 4-N

FIG. 4-O

FIG. 4-P

Figs. 4-N through 4-P: The functional results.
Fig. 4-N: Grasp; note the incision on the dorsum of the wrist through which the index extensor was extricated from the dorsal carpal tunnel and fixed in place by a sling fashioned from the tendon of the brachioradialis.
Fig. 4-O: Holding a pencil.
Fig. 4-P: Pulp-to-pulp pinch.

is deflated, and hemostasis is secured. Following this, the freed petal of the abdominal graft is applied to the wound between the two fingers and is secured with interrupted wire sutures. A catheter which has been made rigid by the insertion of a Kirschner wire is anchored to the nails of the long and index fingers and then bound to the body by a Velpeau bandage.

The second operative procedure is usually performed about seven weeks later. The end of the pedicle of the graft attached to the abdomen is freed, the incision on the palm is retrenched and extended ulnarward, and the skin of the stem of the graft is flattened into the palm and sutured. Following this a second incision is made on the dorsum of the wrist

Fig. 4-G: Preoperative roentgenogram. Note that the index metacarpal has two epiphyses, one proximal and one distal.
Fig. 4-H: Roentgenogram of the hand made after the intermetacarpal cleft was widened and the index finger moved radially.
Fig. 4-I: Roentgenogram made following derotation osteotomy of the index metacarpal. The fragments have been secured together by a malleable wire suture which has also been passed through the proximal epiphysis in order to arrest growth at this end.

FIG. 5-A

FIG. 5-B

Figs. 5-A through 5-K: Shifting of the index finger in a five-month-old girl with congenital absence of the thumb associated with a clawlike deformity of both ulnar fingers.

Fig. 5-A: Dorsal view of both hands.

Fig. 5-B: Photograph made following suturing of one end of the abdominal tube to the widened intermetacarpal cleft of one of the hands. Seven weeks after this procedure, the other end of the tube was weaned from the abdomen and sutured to the surgical cleft of the right hand.

extending along the ulnar border of the index metacarpal. The index metacarpal is then osteotomized at the junction of its middle and proximal thirds. From the abducted position the index finger is rotated until its volar surface faces the corresponding surface of the ring finger, after which the fragments of the osteotomized index metacarpal are secured together with a loop of malleable wire. Since, to function efficiently, the thumb should

Figs. 5-G through 5-I: Functional results.

Fig. 5-J: Functional results in both hands.

Fig. 5-K: The left hand picking up a coin. Despite the fact that derotation osteotomy of the index finger was not done and that the extensor tendon was not extricated from under the dorsal carpal ligament, satisfactory thumb action was obtained.

FIG. 5-C

FIG. 5-D

Fig. 5-C: Preoperative roentgenogram of the right hand.
Fig. 5-D: Postoperative roentgenogram of the same hand. Note the abducted position of the index finger.

FIG. 5-E

FIG. 5-F

Fig. 5-E: Postoperative roentgenogram of the left hand.
Fig. 5-F: Preoperative roentgenogram of the same hand.

FIG. 5-G

FIG. 5-H

FIG. 5-I

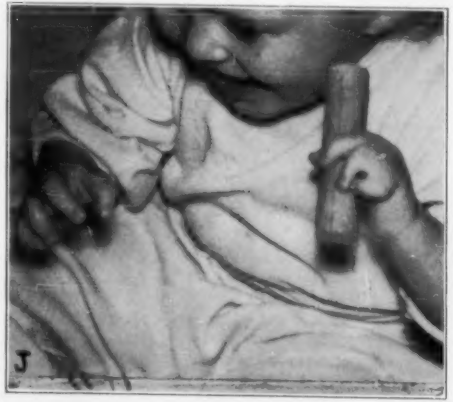

FIG. 5-J

FIG. 5-K

FIG. 6-A

FIG. 6-B

FIG. 6-C

Figs. 6-A through 6-N: Increasing the length of exceedingly short thumbs in a four-year-old boy with bilateral hand deformities. The operative treatment was as follows. A pedicled tube was raised on the abdomen, and one end was attached to the intermetacarpal cleft between the index and ring fingers of the right hand. Seven weeks later the other end of the graft was lifted and connected to the web space between the first and second metacarpals. Still later the graft was divided and apportioned between the two hands. In the left hand when sufficient covering had been secured, the index metacarpal was connected to the thumb metacarpal. This resulted in angulation, which was corrected by osteotomy. The problem in the right hand was more complicated. Two-thirds of the index metacarpal and the existing fragment of first phalanx were added to the tip of the metacarpal of the thumb, fixation being obtained by an intramedullary Kirschner wire. Following union, the entire thumb metacarpal with the added bone was rotated, moved proximally, and added to the remaining third of the index metacarpal. The proximal epiphysis of the thumb was then removed.

Figs. 6-A and 6-B: Dorsal and volar views of both hands.

Fig. 6-C: Photograph showing the two hands connected by a tube graft obtained from the abdomen.

be shorter than the other fingers, the distal fragment of the metacarpal is invaginated into the proximal fragment. Later on it may even be necessary to arrest the growth of the epiphysis at the distal end of the metacarpal, and in the occasional index metacarpal with a proximal epiphysis, this epiphysis may also have to be arrested. Through a small incision over the dorsum of the wrist, the dorsal carpal ligament is split and the extensor tendon is extricated from the wound and shifted to the lateral side of the radius, where it is held by a sling fashioned from part of the tendinous insertion of the brachioradialis. The incisions are closed, a Kirschner wire is passed through the distal phalanx of the rotated and abducted index finger, and a below-the-elbow cast is applied. The wire is removed only after the fragments of the osteotomized metacarpals have completely united. Throughout the period of immobilization, functional exercises of the other digits, the elbow, and the shoulder are encouraged.

In very young infants it is possible to shift the index finger to take the place of the missing thumb without performing derotation osteotomy of the second metacarpal; this is done merely by readjusting the flap of skin used to cover the deepened web space (Figs. 5-A through 5-K). Furthermore, it is not necessary to extricate the extensor tendon from under the dorsal carpal ligament and transpose it laterally. In these infants the end result is obtained with fewer steps in a much shorter time.

Increasing the Length of a Short Thumb

Occasionally babies are born with the index finger missing and the thumb stunted. In these infants resection of the index metacarpal will increase the comparative length of the thumb by widening the web space (Figs. 6-A through 6-N). The actual length of the

FIG. 6-D

FIG. 6-E

Figs. 6-D through 6-G: The results in the right hand.

FIG. 6-F

FIG. 6-G

FIG. 6-H

FIG. 6-I

FIG. 6-J

Fig. 6-H: Preoperative roentgenogram of the right hand.
Fig. 6-I: Two-thirds of the index metacarpal has been added to the thumb metacarpal.
Fig. 6-J: The proximal epiphysis of the thumb metacarpal has been removed and the main shaft has been rotated and connected to the remaining portion of the index metacarpal.

FIG. 6-K

FIG. 6-L

Figs. 6-K through 6-N: The results in the left hand.

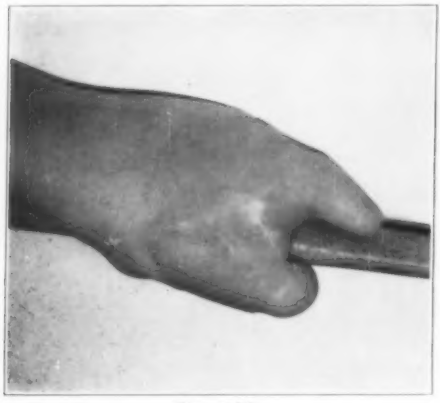

FIG. 6-M

FIG. 6-N

thumb can be increased by the addition of a sizeable segment of the resected metacarpal to the tip of the thumb metacarpal. In this procedure fusion of the two bones is secured by surrounding them either with a pocket of skin supplied by a pedicled graft or with the original integument covering the web space and short thumb. Any angulation that ensues may be corrected by osteotomy. The straightened ray is wrapped partly with the skin of the thumb and partly with skin taken from the adjacent web space, while the resulting defect in the web space is covered with integument supplied by the pedicled graft. In this way, the lengthened thumb is covered with skin which has a sensory nerve supply, while the web space is covered with the grafted skin, which is comparatively insensate. Since the thumb comes in contact with objects far more often than does the web space, it should be given the skin with the properties of perception and feeling.

Osteotomy of the Forearm Bones to Bring the Hand into Functional Position

It is not possible to speak of uncomplicated club-hand deformities in the sense one

Figs. 7-A through 7-J: Treatment of marked clubbing at the wrist in a thirteen-year-old girl by means of carpectomy, fusion of the wrist, and osteotomy of the distal end of the ulna. Separation of webbed digits and transference and rotation of the index finger to replace the missing thumb were also done.

Fig. 7-A: Preoperative roentgenogram.

Fig. 7-B: Dorsal view; note the partially confluent index and long fingers.

Fig. 7-C: Volar view.

Fig. 7-D: Roentgenogram made following carpectomy, fusion of the wrist, and osteotomy of the distal end of the ulna.

Fig. 7-E: Deepening and widening of the cleft between the index and long fingers.

Fig. 7-F: Covering of the cleft with the end of the pedicled graft lifted from the abdomen.

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 7-D

FIG. 7-E

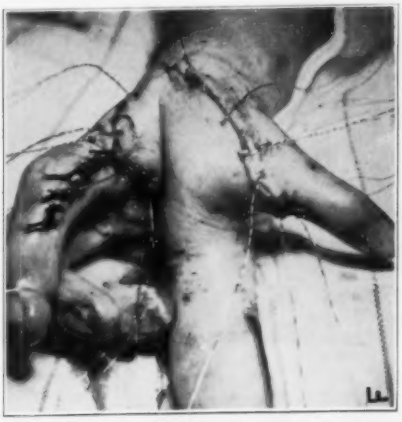

FIG. 7-F

FIG. 7-G

FIG. 7-H

Fig. 7-G: Final roentgenogram.
Fig. 7-H: Pedicled graft and spreader splint.

FIG. 7-I

FIG. 7-J

Fig. 7-I: Hand holding a pencil.
Fig. 7-J: Hand grasping a bar.

speaks of uncomplicated soft-tissue contractures or uncomplicated club-foot deformities. Except in infants with arthrogryposis, athetosis, or cerebral palsy, it is seldom that at birth the hand is twisted into an awkward position without some accompanying deformity. This deformity may be a missing digit or two fingers bound together and in some children the radius or ulna is absent.

The measures commonly used to treat club-foot are not beneficial in the treatment of club-hand. Instead of correcting the deformity, casts and splints have been found to be unnecessary encumbrances which prevent the use of the hand by the child and interfere with its growth. Furthermore, it has been found that in children in whom one of the forearm bones is missing, attempts to replace the missing bone or to construct a bifurcated prong to support the hand at the wrist have produced only doubtful results. In our series, we have corrected the deformity at the wrist by periodically performing osteotomy of the radius or ulna—or of both, if both were present (Figs. 7-A through 7-J). The osteotomy is

done proximal to the distal epiphysis of the bone, and an attempt is made to correct the deformity around both axes (anteroposterior and side-to-side) of the wrist. The purpose is to place the hand in a position of 10 to 20 degrees of dorsiflexion and slight ulnar deviation. If the flexion deformity at the wrist is marked, abrupt correction may overstretch the nerves and damage the blood vessels. The correction should, therefore, be done gradually. In some cases it may even be necessary to wait until the patient is ten years old, at which time carpectomy can be done to allow the wrist to shift into a more normal position; a year or two later the wrist may be stabilized by fusion. It is obvious that in the performance of surgical ankylosis of the wrist, the distal inch of the ulna—if this bone is not missing—should be resected in order to make possible pronation and supination of the forearm and, with it, of the hand. When only the ulna is present, clubbing at the wrist is treated by carpectomy, fusion, and, if necessary, osteotomy. In some instances, clubbing at the wrist is accompanied by absence of the thumb or webbing of the fingers; in these cases, digital insulation or substitution of the index finger for the missing thumb may be done simultaneously with correction of the wrist deformity.

Surgical Treatment of Congenital Ma'formation of the Hand in the Adult

If, for some reason, the patient is not seen until later in life, the attempt to improve the function of the maimed hand must be made with the knowledge that the end result will not be comparable to that which could have been obtained in infancy or childhood.

CONCLUSIONS

In Part I of this paper an attempt was made to extricate the topic of congenital hand malformation from the tangle of nomenclature currently in use and to consider it in terms that can be more clearly understood. Possible causes of these malformations were mentioned on a purely conjectural basis.

In the treatment of the crippled hand, our inclination has been to accept the cosmetic appearance of the hand as we found it—to improve the utility of the hand if possible, but otherwise to leave it alone. Although we appreciate the intricate functions a normal hand performs as an organ of perception and movement, we have restricted our discussion of the functions of the crippled hand, before and after surgery, to such elemental activities as pushing, pinching, or grasping. In evaluating the usefulness of the hand, even in the performance of these elemental activities, we have used as a gauge the degree to which the hand is subservient to the brain. At the same time we have kept in mind the functional dependence of the hand on the segments which connect it to the body and on the integrity of its own nerves and muscles. As a corollary of these considerations, we have concluded that only children who have sufficient intelligence to use their hands purposively and who have good sensibility and muscular control in the malformed hand and stable action of the arm and forearm can be considered eligible for reconstructive surgery.

In our discussion of the surgical treatment of the congenitally malformed hand, we have stressed the importance of performing any necessary surgery early, even in infancy. The fingers should be freed from cramping attachments and placed in good functional position before fixed contracture, stiffness of the joints, muscle atrophy, and adhesion of the tendons can develop. If the surgery is performed in early childhood, not only will the results be better than those which could be obtained later, but also fewer operative steps requiring less time will be necessary.

Ten cases have been illustrated. In the first four cases (Part I) pedicled skin grafts were not used, but in the last six (Part II) these grafts were of paramount importance. Toward the end of Part I, we discussed the diversity of approach possible in the treatment of confluent digits. We stated that if only two fingers are bound together, it is feasible to use local flaps and free skin grafts. In the treatment of multiple syndactylism or of webbing associated with other anomalies, however, we definitely favor pedicled grafts.

In both parts of the paper, the reconstructive procedures are discussed in terms of the discrete functions, such as pinch, grasp, or thumb action, which they are intended to procure. It was not our intention, however, to imply that we have designed particular sets of procedures to accomplish specific functional ends. The procedures we have described—deepening of the interdigital cleft, widening of the web space, derotation or angulation osteotomy, digital shift, ostectomy, or arthroplasty—are to be regarded as tools which the surgeon can vary, amplify, curtail, or alter as he wishes in his efforts to give to a crippled limb a measure of the usefulness of a normal hand.

1. Nicoladoni, C.: Daumenplastik und organischer Ersatz der Fingerspitz (Anticheiroplastik und Daktyloplastik). Arch. f. Klin. Chir., **61**: 606–614, 1900.

Arthrographic Studies of the Shoulder Joint*†

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Many articles in the medical literature attest to the fact that there is a multiplicity of soft-tissue changes in and about the shoulder joint which can cause the symptom complex of pain and restriction of motion. The differential diagnosis is difficult because there is no test that can be consistently relied upon to characterize any one of the various soft-tissue conditions.

This is a report of a study in which contrast-media arthrograms were made of ninety-six problem shoulders. The clinical and arthrographic findings were correlated with the

FIG. 1-A

FIG. 1-B

Preoperative range of flexion and abduction in a man with a tear in the rotator-cuff mechanism. The involved portion of the rotator cuff covered one-quarter of the circumference of the head of the humerus.

pathological findings seen at operation in fifty-four of the cases. The results demonstrate that arthrography, when correlated with a pain-obliteration, abduction-strength test, is superior to any diagnostic method available at present.

These studies were instituted in May 1953, as a result of our experience in the treatment of two patients, seen at about the same time. The two patients, a man and a woman, were in excellent physical condition, were less than fifty years old, and had experienced no previous injury or discomfort in either shoulder. Prior to being seen by us, each had sustained minor trauma; this trauma had been considered insignificant by them and had initially caused only mild discomfort. The clinical course of each had been characterized by gradually progressive discomfort with periodic exacerbations followed by incomplete remissions. Both had consulted several physicians who had diagnosed their conditions as

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FIG. 2

Photograph made at operation, showing the tear in the rotator-cuff mechanism of the patient in Figs. 1-A and 1-B. The biceps tendon appears on the right, and hypertrophic synovial villae in the bursa may be seen at the bottom of the photograph.

bursitis or tendinitis. Conservative treatment, including diathermy and massage, roentgen therapy, systemic administration of cortisone, and injection of a local anaesthetic and hydrocortisone in the painful region about the shoulder, had resulted at best in only temporary relief.

Examination of each of these patients revealed slight atrophy of the scapulohumeral muscles of the involved shoulder, marked tenderness when pressure was applied over the greater tubercle of the humerus and restriction of active and passive motion. When the pain and muscle spasm had been abolished with the aid of a local anesthetic, the range of motion was found to be essentially normal (Figs. 1-A and 1-B). Crepitation was present in both shoulders but was more marked in the involved shoulder. Surgical exploration of the subacromial mechanism was advised.

The man requested another opinion and subsequently was examined by two experienced, nationally known orthopaedists. One advised an exploratory operation; the other made a diagnosis of bursitis and advised further roentgen therapy. The woman was referred by her insurance carrier to the company's consultant orthopaedist. The latter stated there was no injury in the subacromial mechanism and no indication for an operation and recommended further roentgen therapy.

Rather than continue with roentgen therapy, both patients chose to be operated upon. In each a huge rupture in the rotator-cuff mechanism was found (Fig. 2). This defect had created a wide communication between the subacromial bursa and the shoulder joint.

As a result of our experience in these two cases, the following conclusions seem justified:

1. Large tears in the rotator-cuff mechanism may exist in the presence of a normal or nearly normal range of shoulder motion;

2. Such lesions are more common than is generally appreciated and are impossible to recognize with certainty by the usual clinical tests;

3. In such lesions contrast media, injected into the shoulder joint, should pass through the communicating portal, thus establishing the diagnosis, provided no such communication normally exists.

FIG. 3-A

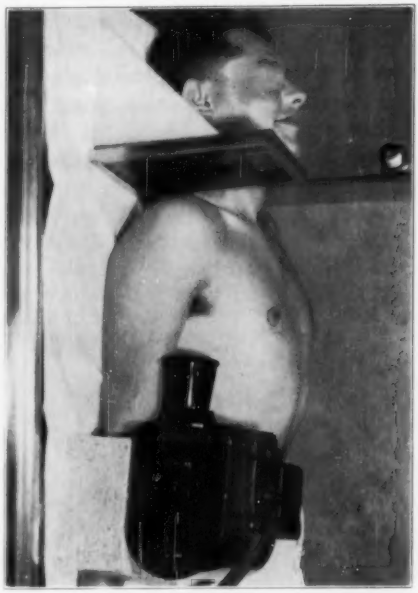

FIG. 3-B

Fig. 3-A: Photograph showing a skeleton placed in position for the making of an axial roentgenogram. Note the intertubercular groove on the humerus.

Fig. 3-B: Photograph showing the position of the shoulder, x-ray tube, and film for the making of an axial roentgenogram.

A review of the medical literature revealed that other authors have reached similar conclusions [3, 5, 6, 7]. The findings of these authors indicate that a communication between the scapulohumeral joint and the subacromial bursa can be detected by contrast arthrography and that normally no such communication exists.

In our review of the literature we were unable to find any report of arthrographic studies made concerning local pathological conditions other than tears in the rotator-cuff mechanism. We were also unable to find a description of a method of selecting the patients who warrant arthrographic study. In this study, therefore, all patients with pain and restriction of motion in the shoulder joint due to local causes were considered candidates for arthrographic study until sufficient data were collected to provide a basis for a method of selection.

TECHNIQUE

The tender region about the shoulder joint is anaesthetized, and the comparative strength of abduction and the range of active and passive motion are determined. Anteroposterior roentgenograms with the shoulder in internal and external rotation are made. Following this the patient is placed in a supine position on the roentgenographic table, and axial roentgenograms are made in order to visualize the intertubercular groove (Figs. 3-A and 3-B). The arm is supported so that it does not lie on the table but is in a neutral position at the patient's side. The skin just below and lateral to the coracoid process is anaesthetized and a three-inch No. 20 spinal needle is inserted into the joint. Twenty cubic centimeters of 35 per cent diodrast solution and an equal amount of distilled water are thoroughly mixed and injected into the shoulder joint under roentgenographic control. The contrast media dilates and fills the joint space. When either forty cubic centimeters of the fluid have been injected or a definite resistance has been encountered, the syringe is detached and ten to twenty cubic centimeters of filtered air are injected. The needle

is then removed. Following careful manipulation of the shoulder joint, photo-timed spot anteroposterior roentgenograms are made with the shoulder in internal and external rotation. Axial roentgenograms showing the intertubercular groove are also made. If the tendon sheath contains the biceps tendon, it will be visualized as a filling defect in the contrast medium.

The examination is relatively painless. In our series there were no complications. Tissues removed from shoulder joints into which diodrast had been injected at periods of from several weeks to over one year previously were found to be indistinguishable microscopically from those taken from shoulders in which no diodrast had been used. The diodrast disappears completely from the shoulder joint in two to three hours after the injection, leaving no roentgenographic trace.

FIG. 4-A

Normal arthrographic findings in a child's shoulder.

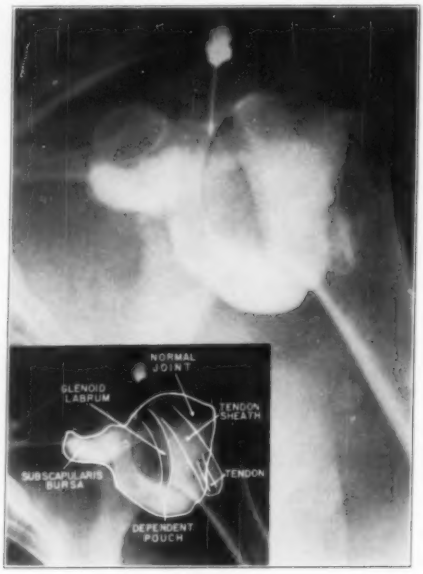

FIG. 4-B

Normal arthrographic findings in an adult's shoulder.

ARTHROGRAPHIC FINDINGS

Normal Findings

The following seven features are considered the normal findings of contrast-media arthrographic study:

1. The capsule, being elastic and expansile, balloons out as it fills with contrast medium.

2. Along the medial side of the neck of the humerus, the capsule extends for about one-half inch and then hangs relaxed to form a small pouch.

3. The subscapular bursa communicates with the shoulder joint; the contrast medium fills this bursa so that it is visualized outside the shoulder joint and just below the coracoid process.

4. The synovial lining of the joint surrounds the biceps tendon and extends down the intertubercular groove for two inches, where it ends abruptly. It fills readily with the opaque medium and is seen as a narrow pouch about the size of a cigarette.

5. The glenoidal labrum is visualized as a band of lesser density extending vertically inside the joint.

6. On the superior surface of the humerus, the capsule ends abruptly at the anatomical neck, where it forms a smooth, sharply defined line.

7. The liquid-volume capacity of a normal adult shoulder joint is approximately twenty cubic centimeters. The only difference revealed by arthrography between an adult's and a child's shoulder is in their liquid-volume capacities (Figs. 4-A and 4-B).

Twenty-six shoulders showed these seven normal arthrographic findings. Of these, fourteen were operated upon for various reasons; the arthrographic findings were confirmed. For the fourteen patients operated upon, the final diagnoses were: calcified tendinitis that did not respond to conservative treatment in three, recurrent glenohumeral dislocations in two, subluxation of the biceps brachii tendon in two, capsulitis in four,

FIG. 5

FIG. 6

Fig. 5: Arthrogram of a shoulder in which there is a huge tear in the supraspinatus tendon. The complete dislocation of the long head of the biceps which was found at operation is not demonstrated in this conventional view.

Fig. 6: Arthrogram showing incomplete rupture of the rotator cuff.

rupture of the tendon of the long head of the biceps brachii muscle in one, and bicipital tendinitis that did not respond to conservative treatment in two. In all of these patients the rotator cuff was found intact and following operation the condition responded as well to treatment as one might expect in each instance. For the twelve patients with normal arthrographic findings, and not operated upon, the final diagnosis was brachialgia secondary to cervical-intervertebral disc syndrome and degenerative arthritis in four, atrophy of the supraspinatus and infraspinatus muscles of undetermined cause in one, so-called bursitis in six, of whom all were referred with this diagnosis. The patients with brachialgia responded to the usual conservative treatment for intervertebral-disc disease, the patients with bursitis responded to conservative treatment with hydrocortone and local anaesthesia. The patient with atrophy of the supraspinatus and infraspinatus muscles refused exploratory operation and we have been unable to trace him.

Of the twenty-six patients with normal arthrographic findings, at least one-half appeared clinically to have what is usually diagnosed as bursitis or tendinitis. The synovial pouch of the biceps tendon was visualized in each case; obviously, if any adhesions were present in these cases, they were insufficient to obliterate the pouch.

Fig. 7: Photograph of a man with rupture of the tendon of the long head of the biceps brachii. There was an associated rotator-cuff tear with resulting loss of abduction power.

Fig. 8: Arthrogram showing acute rupture of the tendon of the long head of the biceps brachii. Following use of a local anaesthetic there was no loss of abduction. The biceps pouch is obliterated by adhesions. The subacromial bursa which was present is not shown.

Fig. 9-A: Arthrogram of the man shown in Fig. 7, demonstrating rupture of the rotator cuff. The biceps pouch is obliterated by adhesions.

FIG. 7

FIG. 8

FIG. 9-A

Abnormal Findings

If there is a significant discrepancy from normal in the liquid-volume capacity of the joint, if an abnormal communication between the scapulohumeral joint and the surrounding tissues is demonstrated, or if the elasticity of the capsule appears altered, the arthrographic picture may be considered abnormal.

RUPTURE OF THE SHOULDER-CUFF MECHANISM

A communication between the scapulohumeral joint and the subacromial bursa is diagnostic of complete rupture of the shoulder-cuff mechanism. The liquid-volume capacity of the joint is increased so that forty cubic centimeters of contrast medium can easily be injected; fluoroscopically, this can be seen pouring out into the subacromial bursa. The bursa is seen as a sharply defined cap perched superior to the humerus outside the shoulder joint (Fig. 5). The subscapular bursa, biceps-tendon pouch, glenoidal

labrum, and small pouch on the medial side of the humerus show no abnormalities. The characteristic arthrographic findings indicative of complete rupture of the rotator-cuff mechanism are (1) an increase in the liquid volume capacity and (2) filling of the subacromial bursa with contrast medium.

In forty-six cases, the arthrograms were interpreted as presenting evidence of complete tear of the shoulder-cuff mechanism. In thirty-five of these cases the shoulder was operated upon, the findings being confirmed in thirty-three. Of the two patients with positive arthrographic findings which were not confirmed at operation, one had an incomplete fracture of the greater tuberosity incurred during convulsive seizures following burhole exploration of the skull for an extradural hemorrhage by a neurosurgeon. The pain was disproportionate to the injury. An arthrogram was made. Subsequent exploration revealed no evidence of a tear and it is unlikely that the diodrast escaped from the joint through the fracture line into the subacromial bursa, a possibility not considered until the subject was reviewed. The other patient was not under our care. The arthrograms were reviewed and the diagnosis of a ruptured supraspinatus was concurred in. The patient was obese and exploration had been made through a small incision. It is entirely possible that the rupture was missed. Sixteen months after operation, the patient still had complaints. Eleven patients were not operated upon for various reasons. Four of these still have pain and restriction of motion. One, treated by means of an abduction splint for two months, is asymptomatic but has reduced abduction strength. Data relative to the rest are unavailable.

FIG. 9-B

Arthrogram showing rupture of the rotator cuff and dislocation of the biceps tendon. This is the only instance in which the subcoracoid bursa was visualized.

INCOMPLETE RUPTURE OF THE SUBACROMIAL MECHANISM

The characteristic arthrographic finding in this condition is interruption of the sharply defined line of the capsule in the region of the anatomical neck. A partial tear creates an ulcer-like crater into which the opaque medium permeates (Fig. 6). This may be seen by fluoroscopic or roentgenographic examination when the humerus is externally rotated. In such a case the liquid-volume capacity is unaltered.

In three cases the arthrographic studies were interpreted as presenting evidence of an incomplete tear. Two shoulders were operated upon and the findings confirmed; the third has remained symptomatic after more than two years.

LESIONS OF THE BICEPS TENDON

Coexisting lesions of the biceps tendon and rotator-cuff mechanism are not uncommon.

Complete Rupture of the Biceps Tendon

Complete rupture of the tendon of the long head of the biceps muscle is easily recognized clinically by the altered configuration of the arm when the muscle is flexed (Fig. 7). An associated lesion in the rotator cuff is usually found accidentally.

Rupture of the biceps tendon was studied arthrographically in three cases. In one of

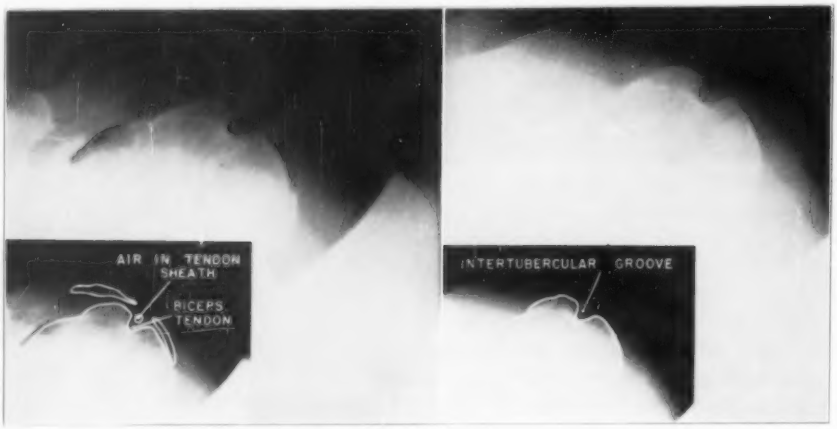

FIG. 10-A

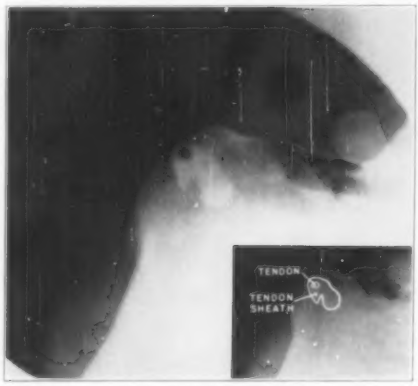

FIG. 10-B

Fig. 10-A: Preliminary (right) and double-contrast (left) axial roentgenograms showing the biceps tendon in the intertubercular groove.

Fig. 10-B: Axial roentgenogram, showing the biceps tendon in the intertubercular groove surrounded by diodrast solution.

these cases there was no evidence of a communication between the subacromial bursa and the joint space (Fig. 8). In the other two there was a communication. In all three cases the shoulder was operated upon and the arthrographic findings were confirmed. In the patient in whom the shoulder-cuff mechanism appeared intact, the biceps tendon was severed just distal to the intertubercular groove. The proximal portion of the tendon had retracted upward and the synovial pouch was completely obliterated by fibrinous adhesions. In the arthrogram of this patient's shoulder, the biceps-tendon pouch was not visualized.

In the two patients with coexisting rotator-cuff lesions (Figs. 9-A and 9-B), there was an increased liquid-volume capacity in the joint. In both cases the subacromial bursa was visualized. In one patient the adhesions between the tendon and the surrounding synovial tissue were sufficient to obliterate the biceps synovial pouch. In the other patient (Fig. 9-B), the biceps-tendon sheath was displaced from the groove.

Dislocation of the Biceps Tendon

Complete dislocation of the tendon of the long head of the biceps, in association with rupture of the shoulder-cuff mechanism, was unexpectedly found in eight cases. Subsequent review of the arthrograms revealed that in some of the arthrograms the bicipital pouch was visualized outside of the intertubercular groove. In the others, however, nothing was found to indicate that the tendon was dislocated. Dislocation of the tendon in the absence of rupture of the rotator-cuff mechanism has also been reported [1]. Since our experience in these cases we have routinely examined all shoulders for such a lesion. To accomplish this, an axial roentgenogram was made in order to determine whether the biceps tendon was present in the groove (Figs. 10-A and 10-B).

Arthrograms and axial roentgenograms were made in thirty-two cases, the biceps

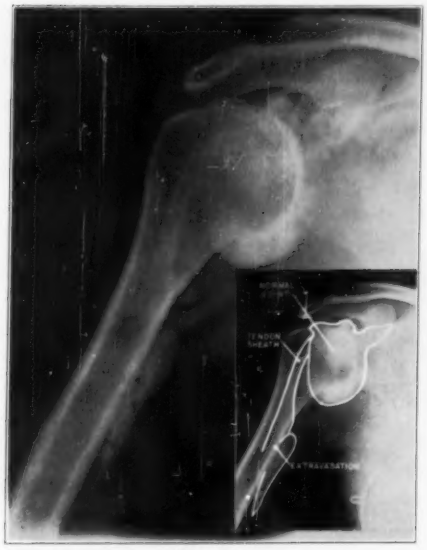

FIG. 11

FIG. 12

Fig. 11: Arthrogram showing soft-tissue extravasion in a patient with subluxation of the tendon of the long head of the biceps.

Fig. 12: Arthrogram showing calcification of the supraspinatus. There is a tear in the tendon.

Fig. 13: Arthrogram showing calcification of the supraspinatus without an associated tear.

tendon being visualized in the intertubercular groove in every instance. In fourteen of these cases, the shoulder was subsequently operated upon and the presence of the tendon in the groove was confirmed. Whether absence of the tendon from the intertubercular groove can be detected and is indicative of a dislocation remains to be proved.

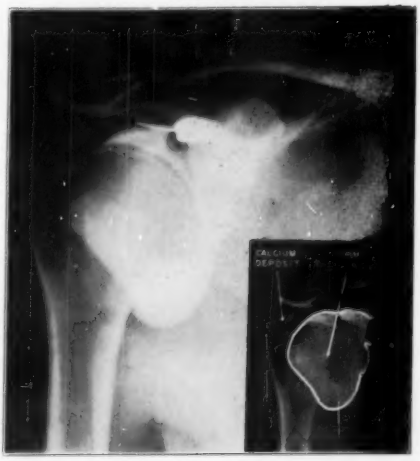

FIG. 13

Subluxation of the Biceps Tendon

Subluxation of the biceps tendon was diagnosed by means of the Abbott-Saunders test in two cases. In one case the diodrast passed down the biceps pouch into the arm, outlining the biceps muscle (Fig. 11). The significance of this finding is questionable; it was present only once in this series of ninety-six shoulders.

Both patients with subluxation of the biceps tendon were operated upon and at operation the diagnosis was confirmed. Fastening the tendon in the intertubercular groove relieved the patients of their complaints.

Degenerative changes in the intra-articular portion of the biceps tendon were present in approximately one-half of the shoulders operated upon. These changes are not detectable arthrographically.

CALCIFICATION OF THE SUBACROMIAL SOFT TISSUES

The presence of calcium in the subacromial tissues does not preclude the possibility of some other lesion being responsible for the patient's symptoms. Until it is proved

FIG. 14

FIG. 15

Fig. 14: Arthrogram of a patient with recurrent dislocation of the shoulder. There is no communication between the joint space and the subacromial bursa, but the joint is relaxed and the subscapularis bursa is enlarged.

Fig. 15: Arthrogram showing a recent scapulohumeral dislocation and a rupture of the rotator cuff. This patient had persistent pain.

otherwise, however, it is logical to assume that calcium, or some indirect effect of its presence, is the cause of the patient's symptoms. In 1941, Bosworth reported that he had found calcium in 2.7 per cent of over 12,000 supposedly normal shoulders and that in 34.6 per cent of the 202 involved shoulders studied, there was some degree of pain or discomfort at some time. Furthermore, it should be remembered that a calcified supraspinatus tendon is a diseased tendon and that diseased tendons rupture.

Arthrographic studies were made of twelve shoulders in which there was calcium in the subacromial tissues. A tear in the rotator-cuff mechanism was demonstrated in seven. Four of these shoulders were operated upon and the tear demonstrated and repaired (Fig. 12). Of the five shoulders with calcified subacromial tissues but without arthrographic evidence of a tear, three were operated upon; in these cases the calcium was removed and the fact that there was no tear in the rotator-cuff mechanism was confirmed (Fig. 13).

DISLOCATION OF THE SHOULDER

Dislocation of the scapulohumeral joint always produces a tear in the capsule. The presence of the tear increases the liquid-volume capacity of the shoulder joint. In the absence of an associated tear in the rotator-cuff mechanism, the material injected intra-articularly passes out of the joint into the region of the subscapular bursa (Fig. 14). If a rupture is present, the subacromial bursa will be visualized despite the decompression that occurs as a result of the tear in the capsule near the glenoidal labrum (Fig. 15).

Nine patients with a history of recurrent dislocation of the scapulohumeral joint were examined. In six patients arthrographic evidence of a tear in the rotator-cuff mechanism was found. Of these, five were operated upon and the presence of the tear was confirmed. Arthrograms of the other three patients showed no evidence of a tear in

FIG. 16-A

FIG. 16-B

Fig. 16-A: Roentgenogram showing subluxation of the glenohumeral joint. The humerus is in an abducted position.

Fig. 16-B: Arthrogram showing an associated tear in the rotator cuff.

Fig. 17: Arthrogram showing a so-called "frozen shoulder."

FIG. 17

the rotator cuff. Two were operated upon, and the arthrographic findings were confirmed. In each instance the liquid-volume capacity of the joint was more than forty cubic centimeters.

These patients constitute a selected group, and it must be remembered that the finding of a torn rotator cuff in two-thirds of a series of patients with a history of recurrent dislocation of the shoulder is not to be construed as indicating the normal frequency of the coexistence of these lesions. The latter is a subject for further study. This series does indicate, however, the value of arthrography in detecting the coexistence of these lesions and suggests that at the time of repair of the dislocation, a tear in the rotator-cuff mechanism should be looked for.

SUBLUXATION OF THE SHOULDER

In the only patient in this series with chronic recurrent subluxation of the shoulder joint, arthrographic study revealed an associated rupture of the rotator-cuff mechanism (Figs. 16-A and 16-B). This finding was confirmed at operation. Treatment consisted in repair of the torn rotator cuff and transplantation of the subscapularis (Magnuson tech-

nique). Three years later the patient had an essentially normal range of motion and was asymptomatic.

CAPSULITIS

The etiology of capsulitis remains an enigma. In patients with this condition there is an organic fixation of the scapulohumeral joint and reduced abduction strength. The purpose of making arthrographic studies of shoulders with this condition was threefold: (1) to determine the presence of a joint space; (2) to establish whether or not the synovial pouch of the bicipital tendon is obliterated; and (3) to determine the presence or absence of a tear in the rotator-cuff mechanism.

Arthrographic studies of twelve patients with capsulitis were made. In each case, reduction of the liquid-volume capacity of the joint space and the presence of a bicipital synovial pouch were readily demonstrable. In no case was a communication between the joint space and the subacromial bursa seen (Fig. 17). To rule out the possibility of obliterative subacromial bursitis, resulting in obscuring of the characteristic arthrographic findings indicative of a torn rotator cuff, four of these patients were operated upon. It was found that a joint space was present and that the joint space, the biceps synovial pouch, and the subacromial bursa were without adhesions. The characteristic finding was that the capsule and coracohumeral ligament were markedly thickened and inelastic. Microscopic study of tissues removed at the time of operation revealed the presence of subacute inflammation. Thickening of the soft tissues and the presence of inflammation have been reported in previous papers[8,9]. The finding of a joint space and bicipital pouch both by arthrogram and at operation in every case does not confirm either Neviaser's description of this condition as adhesive capsulitis or Hitchcock and Bechtol's description of it as being due to peritendinitis.

TABLE I*

Group	Range of Motion**		Abduction Strength	Arthrographic Finding
	Passive	Active		
I (21 cases)	Normal	Normal	Normal	Occasional incomplete rupture (3 cases)
II (43 cases)	Normal	Normal	Reduced	Complete rupture common (37 cases)
III (11 cases)	Normal	Reduced	Reduced	Complete rupture common (9 cases)
IV (12 cases)	Reduced	Reduced	Reduced	No rupture found

* Nine cases of dislocation of the shoulder not included.

** The range of motion and abduction strength were evaluated after pain had been eliminated with the aid of a local anaesthetic.

DISCUSSION

Correlation of the findings of the pain-obliteration, abduction-strength test with the arthrographic and operative findings revealed that it is possible to classify these problem shoulders into four groups (Table I). In the majority of instances rupture of the shoulder-cuff mechanism will be found in Group 2 or 3. Group 2 is the problem group; in this group the test is of most value in differentiating conditions with tears from those in which there are no tears but in which there is reduction in abduction strength. In Group 1, use of the arthrogram is indicated only after the patient has received conservative treatment without beneficial results. Incomplete tear will occasionally be discovered in this group. In Group 4 cases, rupture of the shoulder-cuff mechanism has never been found by us. A similar experience was reported by McLaughlin.

In this study of ninety-six problem shoulders, three main characteristic arthrographic pictures were found. The first, which has seven distinguishing features and is considered

normal, is common to a variety of conditions, including those in which there is no proved primary shoulder disease. The second is indicative of rupture of the rotator-cuff mechanism and is characterized by an increase in the liquid capacity of the joint as well as by visualization of the subacromial bursa. The third, found only in the presence of organic scapulohumeral fixation, is characterized by an inelastic, non-distensible capsule and by considerable reduction in the size of the joint space; the other characteristics of this picture are normal.

The arthrographic findings were correlated with the pathological condition present at the time of operation in fifty-four instances. Of the thirty-five patients in whom the diagnosis was complete rupture of the shoulder-cuff mechanism and upon whom operations were subsequently performed, thirty-three had a demonstrable lesion. Of these thirty-three patients, eight had a coexisting complete dislocation of the tendon of the long head of the biceps, two had complete rupture of the biceps tendon, four had a calcified supraspinatus, and three had a history of recurrent dislocation of the shoulder joint with rupture of the capsule at the glenoidal labrum.

CONCLUSIONS

1. Arthrography of the shoulder is a simple, safe, easily interpreted clinical test which is unusually accurate and which provides information that would otherwise be unavailable without an exploratory operation.

2. An arthrographic study is indicated in any case in which the diagnosis is doubtful.

3. The pain-obliteration, abduction-strength test provides an excellent method of selecting candidates for arthrographic study.

4. Capsulitis is an inflammatory condition infrequently, if ever, associated with rupture of the rotator-cuff mechanism.

5. Coexistence of lesions of the biceps tendon and rotator cuff is common.

6. Rupture of the supraspinatus tendon is a common complication of recurrent dislocation of the shoulder and should be looked for by arthrography or at operation.

7. Coexistence of calcification of the subacromial tissues and rupture of the rotator-cuff mechanism is not uncommon in the presence of reduced abduction strength.

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Cineroentgenography of the Normal Cervical Spine*

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Cineroentgenography is the permanent, dynamic registration of fluoroscopic images on motion-picture film. Within two years following Röntgen's discovery, efforts were made to produce such movies [5], since the need for that method of clinical investigation was appreciated even then. These early attempts, similar to animated drawings, were static roentgenograms arranged in sequence which failed to depict dynamic flowing action. Reynolds, who began his experiments in 1921 [5], was probably the first to produce satisfactory films by directly photographing the image on the fluoroscopic screen. The further use of this method is indicated for clinical investigation, particularly of pathological conditions.

METHODS

1. *The Direct Method:* The camera directly records the fluoroscopic screen.

2. *The Indirect Method:* An image intensifier is interposed between the patient and the recording camera.

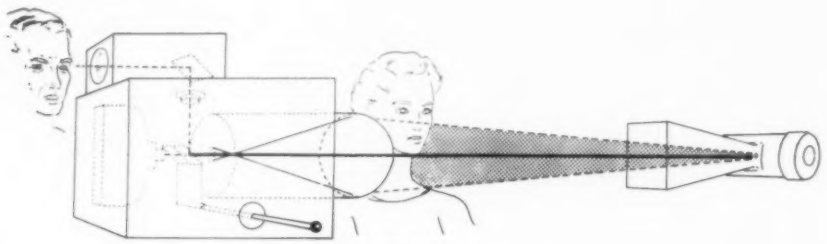

FIG. 1

Diagram of the equipment used to produce the films which form the basis for this study. Interposed between the camera and image intensifier is a monitoring system through which the image can be viewed while it is being recorded.

The direct method is apparently impractical; even with the fastest photographic emulsions and optics available, the quantity of roentgen rays necessary to produce an image of recordable brilliance on the fluoroscopic screen reaches the dangerous level, both for patient and operator. Hence, only sequences of short duration are possible. This technique is also difficult to monitor.

The need for a practical means of image intensification for medical, as well as for other fields, led Langmuir to perfect the principle in about 1937 [3, 4]. The image-intensifier tube resulted, making possible the indirect method of cineroentgenography.

The advantage of the indirect method is that an extremely brilliant image is produced with relatively small amounts of radiation. To describe the apparatus simply, the roentgen rays pass through the patient and impinge on a fluoroscopic screen five inches in diameter at one end of the tube. The rays then pass through the tube where they are electronically accelerated and demagnified. An image only one-half inch in diameter is produced on a fluoroscopic screen at the tube's outlet. This final image is very brilliant and is easily photographed on medium-speed panchromatic film by a motor-driven conventional motion-picture camera, at a rate of twenty-four frames per second. The process of light intensification within the tube is analogous to the focusing of sun rays with a magnifying glass.

* The motion picture forming the basis for this paper was presented at the Audio-Visual Program of the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26 and 29, 1957.

The roentgen-ray exposure for the indirect method as presently used is well within safe limits. The average skin dose is 6 r per minute of filming [7]. This is about one-third less than the amount absorbed during an anteroposterior and lateral roentgenographic examination of the lumbar spine in an average individual [6].

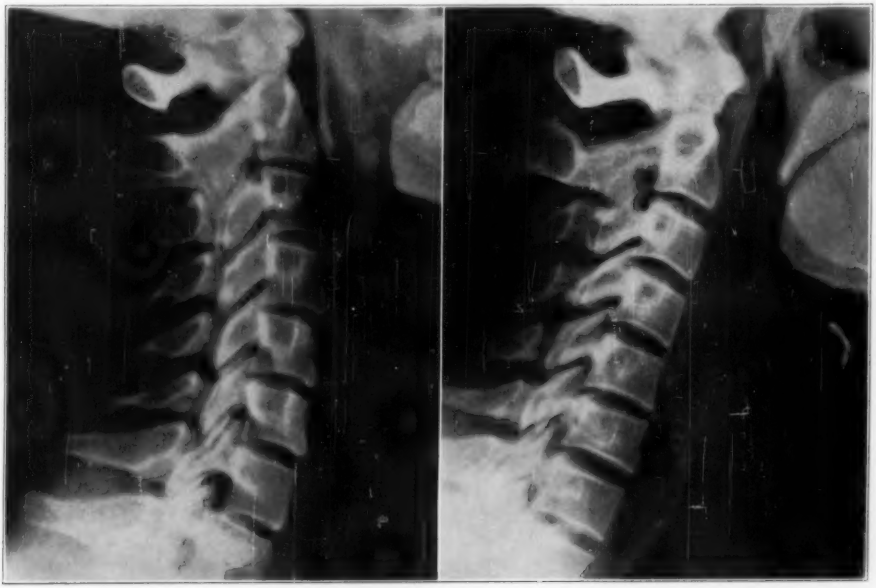

FIG. 2

Roentgenograms of cervical spines of normal individuals in the neutral position. In one a lordosis is present, while in the other there is a linear pattern.

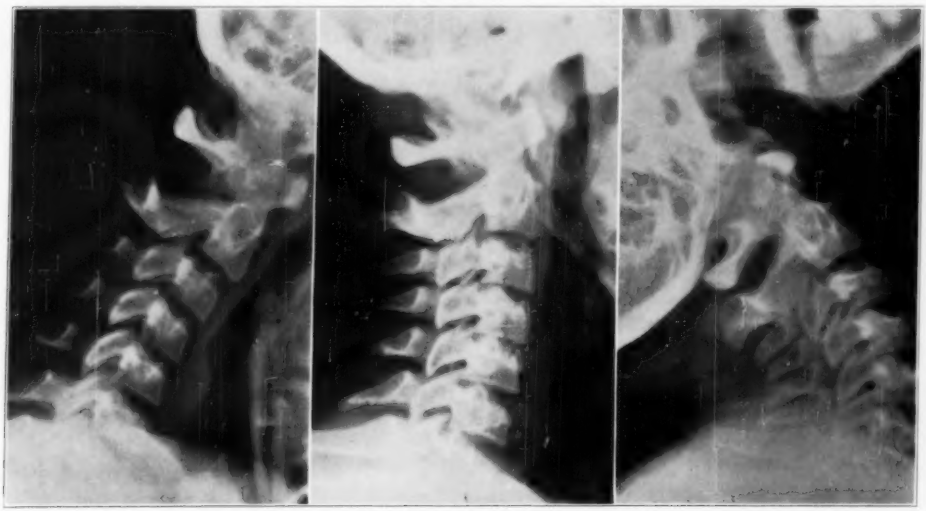

FIG. 3

In the neutral position (center), note the space between the occipital bone and the posterior tubercle of the first cervical vertebra, and the space between the posterior tubercle of the first and the spinous process of the second cervical vertebrae. In flexion these spaces widen only slightly. In extension the components almost come in contact.

Equipment (Fig. 1)

A roentgen-ray source, an image-intensifier tube, a motion-picture camera, and an optical system for continuous monitoring are the equipment necessary.

A fractional focal-point roentgenographic tube with a 0.3 millimeter gap and conventional filtration is the source which is essential for films of good resolution and maximum detail. Although the heat-storage capacity of this type of tube is somewhat limited, the dosage requirements are so low that a complete examination can be accomplished without danger of overloading. The use of a fractional focal-point tube permits enlargement technique without loss of detail. The image can be enlarged four times by placing the patient closer to the source of the rays. This is of particular value in examination of the articulation of the first and second cervical vertebrae.

Sixteen-millimeter film was selected for this study because it is more economical and simpler to handle than larger films. Projection apparatus for sixteen-millimeter film is readily available and there is no loss of detail due to use of the smaller film.

It is of utmost importance that a means of monitoring be interposed so that the image may be seen during recording. The monitoring system used in the production of this film does not require dark adaptation (Fig. 1) and it permits the operator to instruct the patient during photography.

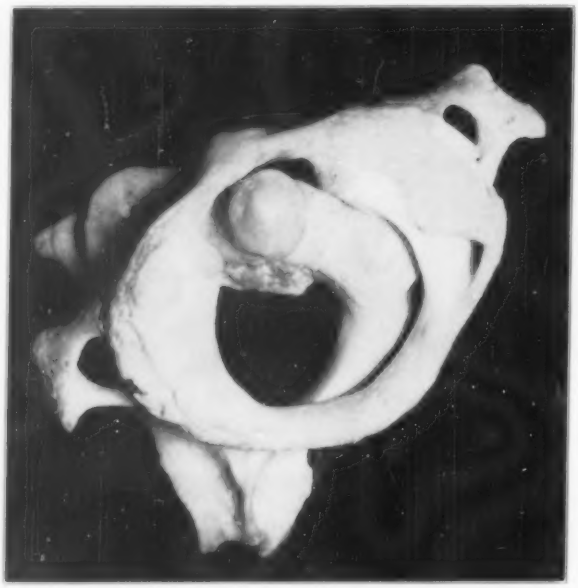

FIG. 4

The atlas is shown in the rotated position on the axis. The pivot is the eccentrically placed odontoid process. In rotation, the wall of the vertebral foramen of the first cervical vertebra decreases the opening of the spinal canal between the two segments.

THE CERVICAL SPINE AS A WHOLE

This paper is an attempt to describe some of the motions visualized in the cineroentgenogram which must be seen to be fully appreciated.

In the neutral anatomical position the cervical spine assumes a symmetrical lordosis in lateral projection from the first to the seventh vertebrae. Above this, a reversal of the angle allows the head to rest in a level plane. In some normal individuals the segments are arranged in a linear pattern above the fifth cervical vertebra (Fig. 2).

To allow the extensive mobility characteristic of this area of the spine, the local ligamentous structures must be sufficiently relaxed; yet they must be able to check motion before dislocation occurs.

In this paper the cervical spine will be considered regionally.

ATLANTO-OCCIPITAL ARTICULATION

The only motions permitted at this joint are flexion and extension; the skull and first cervical vertebra otherwise move as a unit. From study of the film it appears that little flexion occurs (about 10 degrees), while the range of extension is much greater (about 25 degrees) (Fig. 3).

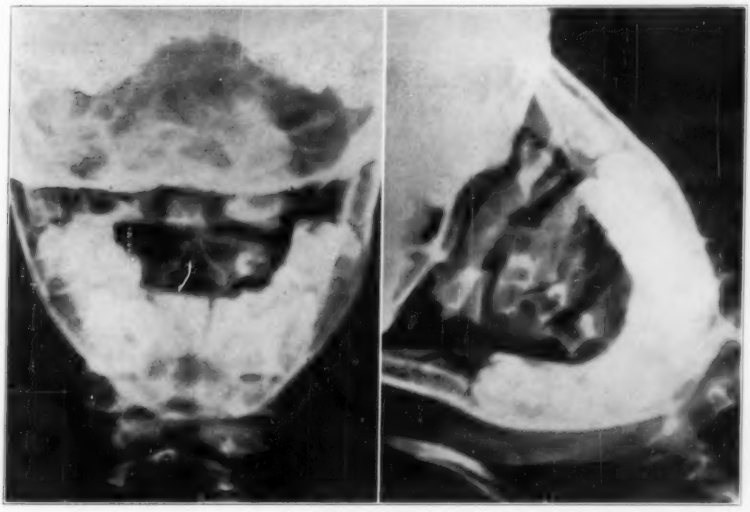

FIG. 5

In the neutral position the spinous process of the second cervical vertebra, the odontoid process, and the symphysis menti are in the median plane. When the head is tilted to one side the spinous process of the second cervical vertebra deviates to the opposite side, indicating rotation of this vertebra.

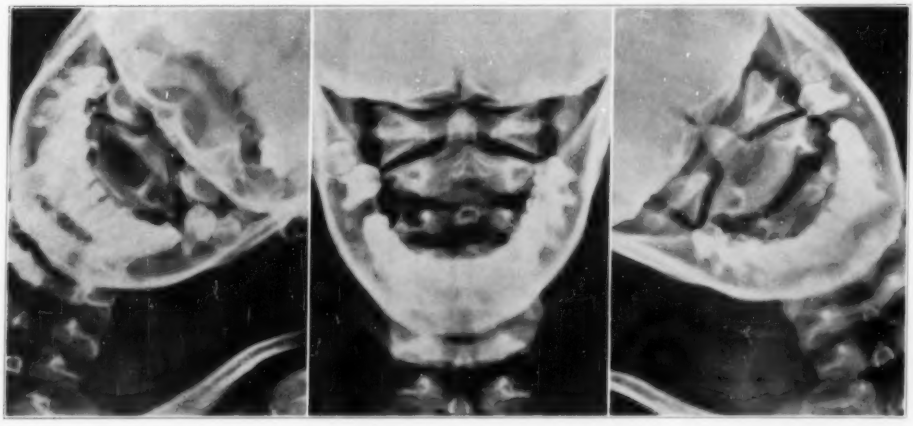

FIG. 6

In the neutral position the space between the first and second cervical vertebrae is bilaterally equal. In lateral tilt the atlas may shift to the side of the tilt, the space becoming narrower on one side accordingly.

ATLANTO-EPISTROPHIC ARTICULATION

In order that this area may be properly studied, the subject must be cooperative and well trained in the necessary motions. A proper system of monitoring is essential, and the operator must be adept in it. The open-mouth view must be used, and, for a shadow-free picture, the patient should hold his tongue on the floor of the mouth.

This joint is the most mobile region of the spine. While it is generally thought of as a pivotal joint, four very distinct motions occur here: rotation, flexion, extension, and vertical approximation.

Rotation

In the first part of rotation, the skull and first cervical vertebra move as a unit on the immobile second cervical vertebra below. The pivot of this rotation is the odontoid process of the second cervical vertebra. This pivot is laterally central but is anteriorly eccentric. It is enclosed in the anterior arch of the atlas and held there by the transverse ligament. In rotation, the wall of the vertebral foramen of the first cervical vertebra therefore swings laterally to a considerable extent across the foramen of the second cervical vertebra. This decreases the opening of the spinal canal between these two segments and angulates the canal during rotation (Fig. 4). The full extent of rotatory motion of the cervical spine is as great as up to 90 degrees. From study of the roentgenogram, it appears that about half of the rotation of the neck occurs at the atlanto-epistrophic articulation before the spinous process of the second cervical vertebra deviates. Thereafter there is participation in rotation by the remaining cervical vertebrae below the second in rapidly decreasing amounts.

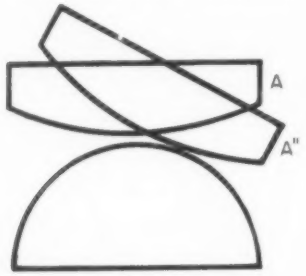

FIG. 7

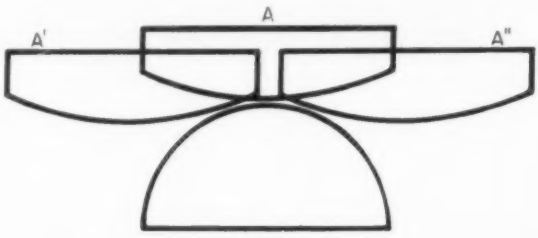

FIG. 8

Fig. 7: The lower figure diagramatically represents the superior convex facet on the second cervical vertebra. The upper figure represents the corresponding inferior facet on the first cervical vertebra. *A* represents neutral; *A"* the position of flexion.

Fig. 8: With the upper and lower figures the same as in Fig. 7, *A* represents neutral, *A'* and *A"* represent positions of rotation.

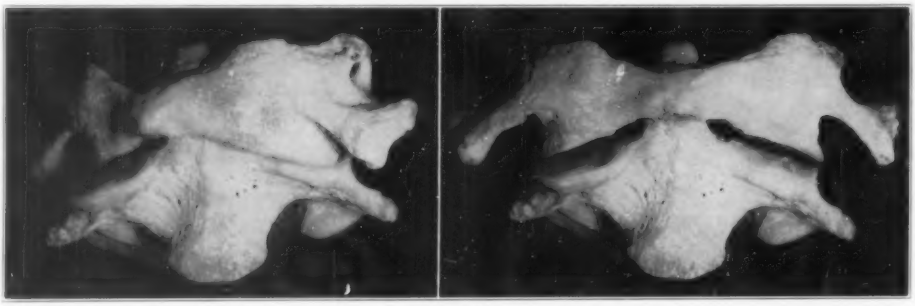

FIG. 9

There is an apparent decrease in the joint space between the first and second cervical vertebrae as rotation occurs. This is indicated diagramatically in Fig. 8.

We were surprised to find that lateral flexion of the head with the chin in the sagittal plane produces more associated rotation of the second cervical vertebra than does even simple rotation of the head. The odontoid and spinous processes of the second cervical vertebra and the symphysis menti are in the median plane only when the head is in the normal position. When the head is tilted or rotated to one side, the spinous process of the second cervical vertebra and of those below deviate to the opposite side decreasingly from above downward, indicating rotation of these vertebrae (Fig. 5).

During lateral tilt the first cervical vertebra may shift to the side of the tilt in some normal subjects, while the space between the first and second cervical vertebrae becomes narrower on that side (Fig. 6).

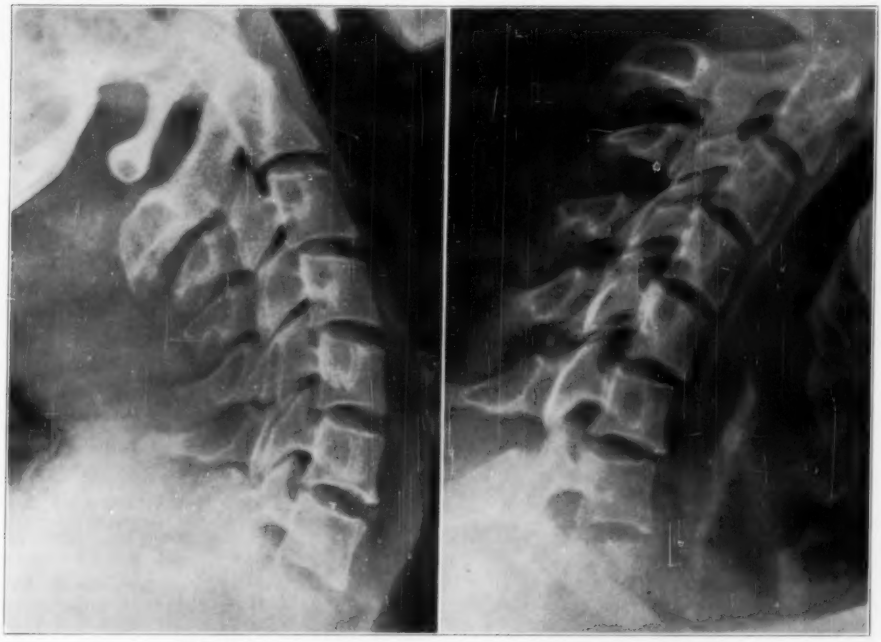

Fig. 10-A

Fig. 10-B

Figs. 10-A through 10-D: In flexion, the higher vertebrae shift anteriorly over those below.

Fig. 10-C

Fig. 10-D

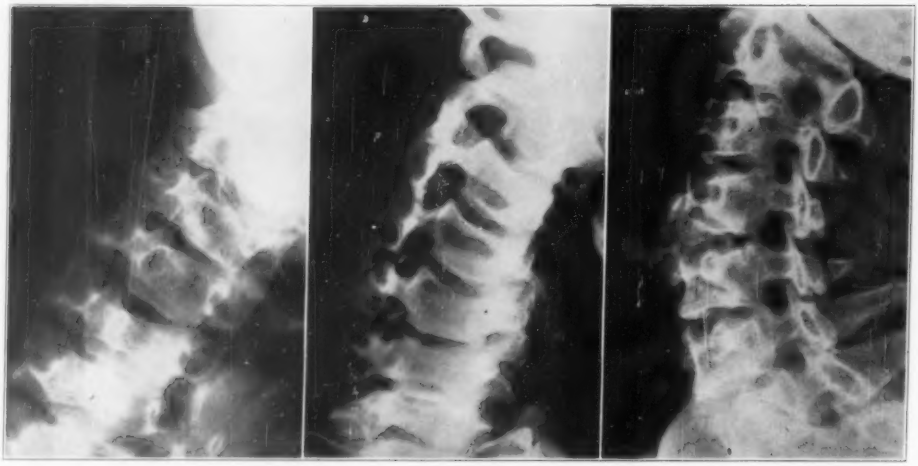

FIG. 11

FIG. 12

Fig. 11: In lateral flexion (left), the facets on the concave side overlap, while those on the convex side glide apart. In rotation (center), the facets overlap on the side being rotated to and glide apart on the opposite side. In full extension, the facets have overlapped to the limit and adequate foramina are present.

Fig. 12: The main axis of flexion in this normal individual appears to be at the level of the fifth cervical vertebra.

Flexion and Extension

On the cineroentgenographic record the posterior tubercle of the first cervical vertebra and the spinous process of the second cervical vertebra separate in flexion and approximate in extension. These motions are limited (about 15 degrees) when compared with the range of rotation permitted. As in the atlanto-occipital articulation, extension is the greater, being possible up to 10 degrees, while flexion is only 5 degrees (Fig. 3). This motion occurs because the superior facets of the second cervical vertebra are convex while the corresponding inferior facets on the first cervical vertebra are not concave, but are, in effect, flat. These flat facets rock forward and backward on the convex facets below (Fig. 7). The articular surfaces of the odontoid process, the anterior arch of the first cervical vertebra anteriorly, and of the transverse ligament posteriorly are shaped to allow this motion to occur.

FIG. 13-A

FIG. 13-B

Figs. 13-A, 13-B, and 13-C: The vertebral artery is represented by a piece of rubber tubing. Note the wide excursion of the "artery" when the vertebrae are rotated.

FIG. 13-C

Vertical Approximation

Vertical approximation, or telescoping of the first cervical vertebra on the second, occurs in rotation. This motion is due to the relatively flat facet on the inferior surface of the first cervical vertebra in apposition to a relatively convex superior facet on the second cervical vertebra. As these two facets slide forward and backward on each other, as they do in rotation, the superior element is raised or lowered on the condyloid surface of the convex facet below (Fig. 8). When the first cervical vertebra is in the neutral position with respect to the second cervical vertebra, a joint space can be seen on the cineroentgenogram between the facets in the open-mouth view. In this position, the first cervical vertebra rests on the summit of convexity of the superior facet on the second cervical vertebra. As rotation occurs, this joint space decreases in direct proportion to the amount of rotation (Fig. 9). The upward and downward riding in rotation is the motion responsible for the "obliteration" of this joint space.

THE CERVICAL SPINE BELOW THE SECOND CERVICAL VERTEBRA

The whole cervical spine appears to lengthen during flexion and to shorten during extension, probably due to a change in lordosis since no actual lengthening or shortening occurs. Below the second cervical vertebra, flexion, extension, lateral flexion, and rotation occur between each individual element.

Intervertebral-Disc Changes

The disc structures are, because of their resilience, fully as important in permitting motion below the second cervical vertebra as are the articular facets. In the neutral position, these discs are roughly rectangular in outline. As the spine assumes a forward flexed position, the higher vertebra shifts anteriorly over the one below (Figs. 10-A through 10-D). At the same time, the disc space narrows anteriorly and widens posteriorly. In the act of extension, the situation is reversed. This sliding with its associated disc

deformation is fairly well maintained from the first cervical vertebra downward to the sixth. In the upper region, the total sliding motion is greatest. There is little sliding in the lower two segments and the outlines of the disc spaces are only slightly altered. Associated changes in the outline of the intervertebral-disc structures are also evident in other motions.

Articular Facets

For satisfactory visualization of the articular facets, the oblique view is essential. In all motions, disc deformation and facet gliding occur together. The superior articular facet surfaces point backward and upward, while the inferior surfaces point downward. It is this inclination of the facets that is responsible for the forward and backward shift of the vertebral body during flexion and extension. In flexion, the superior facets glide upward and forward in relation to the ones below and the vertebral body shifts forward a corresponding amount. In extension, the opposite shift occurs. In the more mobile areas, the amount of shift will of course be greater. In full flexion, the facets are almost at the point of subluxation.

In lateral flexion, the articular facets on the concave side imbricate while those on the convex side ride apart. Rotation always accompanies lateral flexion so that no cineroentgenographic record could be made of lateral flexion without rotation. The facets imbricate on the side being rotated to and glide apart on the opposite side (Fig. 11).

Foramina

The intervertebral foramina are best visualized in the oblique projection. These passages are created by a notch in the superior surface of the pedicle of the lower vertebra and a corresponding notch in the pedicle of the upper. In full flexion the foramina enlarge and in extension they diminish. However, adequate foramina are apparent even when the facets are fully imbricated (Fig. 11).

The Level of the Fifth Cervical Vertebra

In many instances greater flexion occurs at this interval than at any other interspace below the second cervical vertebra, even in apparently normal individuals who have had no difficulties with the neck (Fig. 12).

THE VERTEBRAL ARTERY

This artery in most instances enters the foramen of the transverse process of the sixth cervical vertebra and ascends through the remaining transverse processes to enter the skull. It is protected throughout its course by the transverse processes, except between the axis and atlas where about 1.5 centimeters of the artery lies outside of the canal, subject to the stress of the great rotatory motion between these upper two segments.

In rotation, this important artery is pulled forward and backward by the action of the first cervical vertebra moving on the second (Figs. 13-A through 13-C).

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Cervico-Occipital Fusion for Congenital and Post-Traumatic Anomalies of the Atlas and Axis*

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Since 1943, nine patients have had cervico-occipital fusions performed at the Mayo Clinic. Several excellent articles on the treatment of fracture-dislocations of the cervical portion of the spinal column appear in the literature. Rogers [8] recently summarized his experience in the management of eighty-seven lesions in seventy-seven patients who had sustained fractures and dislocations of the cervical spine. Two of the patients in his series underwent fusion of the occiput to the first, second, and third vertebrae. They retained only 10 and 20 per cent of rotation, respectively, whereas two patients who underwent fusion of the first and second vertebrae retained 50 per cent of rotation. Kahn and Yglesias, in 1935, reported a case of progressive atlanto-axial dislocation treated by cervico-occipital fusion. Cone and Turner, in 1937, and Rogers [7], in 1942, reported similar cases. Blockey and Purser recently analyzed fifty-one cases of fracture of the odontoid process; forty of the cases were reported by other surgeons and eleven were their own.

It is probable that some of the dislocations which have been thought to be entirely due to trauma were primarily due to congenital anomalies of the atlas or axis. Trauma, sometimes minor, may have called attention to the abnormality when roentgenograms were made. McRae, in the course of a review of the roentgenographic findings in syringomyelia and syringobulbia at the Montreal Neurological Institute, found that 38 per cent of the patients had bone abnormalities in the region of the foramen magnum. In a further study of twenty-eight cases of occipitalization of the atlas, twenty-one cases of pure platybasia or basilar invagination, eleven cases of separate odontoid process of the axis and six cases of chronic atlanto-axial dislocation, he found that in a third to a half of the cases in each group, the conditions were asymptomatic. In the other cases variable symptoms and signs were present which suggested multiple sclerosis, syringomyelia, syringobulbia, or brain tumor. McRae pointed out that in several cases in his latter two groups the abnormalities were certainly congenital and others probably were of the same nature. He was of the opinion that it was impossible to decide in adults whether one was dealing with an old ununited fracture of the dens or an anomaly. After reviewing the cases of separate odontoid processes reported in this paper, it is my opinion that in the majority of patients instability of the atlas on the axis resulted from a congenitally separate or short odontoid process. It cannot be denied that in some cases a separate odontoid process demonstrated in later life may be the result of an epiphyseal separation. Blockey and Purser pointed out that if separation of the odontoid epiphyses resulted from trauma, union should result quickly, and the separation would not persist as it did in our cases. In one of the cases to be reported here it may be assumed that epiphyseal separation occurred when the patient was sixteen months of age and this accounted for a separate odontoid process demonstrated at the age of sixteen years.

It was interesting to note that in two cases encountered at the Mayo Clinic the onset of symptoms, according to the history obtained, coincided with an infectious process, one a throat infection and the other mumps. The patient having mumps was a child; he

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had not had any trauma to the neck and there is no doubt but that he had a congenital anomaly. The other patient gave a history of trauma severe enough to produce a dislocation of the atlas on the axis, but symptoms which persisted did not begin until six months later when an infection developed in the throat following tonsillectomy. One wonders how many patients having dislocation of the atlas on the axis after infection may have an underlying congenital anomaly or previous injury which is the real basis for the instability. Grogono reported two cases of recurrent displacement after infection in the neighboring tissues despite immobilization in plaster. If infection is superimposed on a congenital anomaly or on an old traumatic condition, treatment may not be so simple as Watson-Jones has indicated. Nicholson noted that in four of fifteen children with dislocations of the atlanto-epistrophic joint, recurrence followed successful reduction. He preferred fusion rather than surgical fixation as the means to correct it.

INJURY TO THE SPINAL CORD

Of the nine patients having cervico-occipital fusion for congenital anomalies, fractures, and dislocations of the atlas or axis, three had neurological deficits of varying degrees at the time of their examinations at the Mayo Clinic. Five others gave histories which suggested temporary injury of the spinal cord, nerve roots, or the bulb.

DISLOCATIONS DUE TO CONGENITAL ANOMALIES OF THE AXIS OR ATLAS WITHOUT A HISTORY OF SIGNIFICANT INJURY

There were two patients in this group. Spillane, Pallis, and Jones recently reported the cases of six patients with congenital anomalies which were quite similar to those encountered at the clinic in Case 1. Because of the age of the patient, the sequence of events in Case 1, and the similarity of the cases reported in the group of congenital anomalies associated with injury to Case 2, these two cases will be reported in more detail than others.

Case 1. A child was registered at the clinic on the date of his birth, August 20, 1946, but following his dismissal from the hospital with his mother he was not seen again until December 12, 1950, when he was returned because of pharyngitis. On May 1, 1951, he sustained a laceration of the cornea of the right eye from a puncture wound caused by a small fragment of wire. Following this injury an adherent leukoma and a traumatic cataract developed. In spite of several surgical procedures, he lost almost all vision in the right eye. In July 1952, when almost six years old, a physician in the Section of Ophthalmology at the clinic noted that the child tended to tilt his head to the right. Convergent strabismus on the left had developed after injury of the right eye.

On January 13, 1953, the child was registered in the Section of Pediatrics because of a stiff and painful neck which had begun with the onset of bilateral mumps (parotitis) three weeks previously. On examination it was noted that the chin was rotated to the right and the head was tilted slightly to the left. The right shoulder was slightly elevated and all motions of the neck were resisted and painful. Several attempts were made to obtain satisfactory roentgenograms but because of the torticollis such was not possible. The sedimentation rate of erythrocytes was elevated to fifty-nine millimeters in one hour (Westergren method). By January 17, 1953, definite improvement was evident and by the next day motions were almost normal. However, two weeks later the torticollis and pain recurred.

The child was then hospitalized for observation, head-halter traction, and additional roentgenograms. Just before his dismissal from the hospital, after two weeks of traction, a plaster-of-Paris cast was applied. During the two months that the child was in traction and wearing the cast, he was reasonably comfortable.

Additional roentgenograms (Figs. 1-A and 1-B) and tomograms revealed congenital fusion of the atlas to the occiput, fusion of the second and third cervical vertebrae, a separate odontoid process, and asymmetry in the articulations between the atlas and axis with forward dislocation of the atlas when the neck was flexed. The roentgenographic findings would be classified by some as consistent with a Klippel-Feil syndrome.

When the cast was removed, the torticollis and pain recurred, and a four-poster type, cervical-neck brace was applied. Two months later this was replaced with a celastex jacket which was worn for one year. Although roentgenograms at this time showed slight increase in the anterior displacement of the atlas on the axis, it was felt that the neck was more stable and the brace was discarded gradually. It was advised that contact sports, bicycling, and ice skating be avoided.

The child was examined in August 1955, one year after the brace was discarded. He was not having pain. Motion of the neck was still limited and slight atrophy of the right side of the face was present.

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Case 1. Lateral and anteroposterior views of the upper cervical portion of the spinal column of a child who was approximately ten years old at the time of cervico-occipital fusion. There is congenital fusion of the atlas to the occiput and of the second and third cervical vertebrae. The odontoid process is separate and there is asymmetry in the articulations between the atlas and axis.

Fig. 1-C: Roentgenogram made six months after cervico-occipital fusion.

FIG. 1-C

Five months later, January 17, 1956, the child was returned to the clinic because of a recurrence of pain, marked limitation of motion and torticollis which had begun with the onset of an upper respiratory infection. New roentgenograms did not show evidence of additional abnormalities. The child, who was now nine years old, was again fitted with a neck brace and cervico-occipital fusion was advised—this to be performed at the end of the school year.

On July 11, 1956, cervico-occipital fusion was performed by means of a modification of the technique of Cone and Turner. A graft was removed from the left tibia. The child was then placed in a sitting position with the head supported on a cerebellar rest. Exposure was carried out by a member of the Section of Neurosurgery. The posterior arch of the atlas was noted to be asymmetrical and fused to the occiput, and the second and third cervical spinous processes and laminae were fused. Abnormal mobility between the atlas and axis seemed to be present. Holes were placed in the base of the occiput and beds were prepared on the laminae and spinous processes of the fused second and third cervical vertebrae. The grafts were wired to the occiput and the fused spinous processes with seven-strand Fagesta wire. After closure of the wounds, the patient was placed in a previously prepared cervical brace.

The child was allowed to go home two weeks after the operation. Immobilization with the brace was continued for almost six months. Roentgenograms made on January 3, 1957 (Fig. 1-C) showed evidence of firm fusion from the occiput to the congenitally fused spinous processes of the second and third cervical vertebrae. The child, when last examined on May 2, 1957, ten months after operation had almost normal motions of the neck (Figs. 1-D through 1-I) for the first time since he had been observed in the Section of Pediatrics in January 1953. The mother stated in January 1957, that in her opinion, the child was really comfortable for the first time in four years. At that time it was advised that normal activities be allowed.

This child, who accidentally lost most of the vision of his right eye, had an infectious disease (mumps) at the age of six years after which acute torticollis developed which was proved to be due to congenital anomalies with subluxation of the atlas on the axis. After comparative freedom from discomfort for two years, the acute symptoms recurred with

FIG. 1-D

FIG. 1-E

FIG. 1-F

FIG. 1-G

FIG. 1-H

FIG. 1-I

Figs. 1-D through 1-I: Patient demonstrating range of motion of cervical part of spinal column ten months after operation.

FIG. 2-A

FIG. 2-B

Figs. 2-A and 2-B: Case 2. Lateral and anteroposterior views showing an anterior dislocation of the atlas on the axis with a congenital anomaly of the dens. Note the separate odontoid process which is also displaced anteriorly in the lateral view.

Fig. 2-C: Roentgenogram made six months after cervico-occipital fusion and decompression of the spinal cord.

FIG. 2-C

the onset of an infection of the upper respiratory tract. Definitive treatment was by cervico-occipital fusion at about ten years of age resulting in complete relief.

CASE 2. A fourteen-year-old boy had been in normal health until May 1, 1949. On this day he had been running a foot race, when he had noted the sudden onset of weakness in his legs and had collapsed. He had had tetraplegia for twenty-four hours and was then normal until June 19, 1949, seven weeks later, when he was standing on a diving board and suddenly fell into the water. He did not strike his head. When pulled from the water, he was paralyzed below the neck. Again movement of the extremities returned to almost normal in twenty-four hours. Nine days later, on June 28, 1949, he was first registered at the clinic. He wore a Thomas collar and complained of numbness and weakness of the left hand. Neurological examination revealed a deficit in the left upper extremity, and the Babinski reflex was positive bilateraliy. Roentgenograms showed a short odontoid base with a separate process and an anterior dislocation of the axis on the atlas (Figs. 2-A and 2-B).

On July 8, 1949, with the patient in a prone position, a member of the Section of Neurosurgery exposed the base of the occiput and the posterior arches of the first three cervical vertebrae. The arches of the atlas and axis were more than an inch (2.5 centimeters) apart and there was no ligamentum flavum between these structures. Decompression of the spinal cord was carried out by enlarging the foramen magnum and removing much of the posterior arch of the atlas. At the latter level the dura mater was tense, and the spinal cord bulged slightly posteriorly. Two holes were made in the outer table of the occipital bone with a perforator, and bone grafts which had been removed from the left tibia by one of my orthopaedic colleagues were wired in beds prepared from the occiput to the second cervical vertebra. Two weeks later a plaster-of-Paris cast was applied, and immobilization was continued for almost six months. The neurological deficit had cleared completely, but the Babinski reflexes were still positive three months after the fusion. Roentgenograms made six months after operation showed firm fusion with extension of the bone grafts to the spinous process of the third cervical vertebra (Fig. 2-C). The patient was last examined at the clinic on July 8, 1950, one year from the date of his operation; he had no complaints and stated that he had been doing heavy farm work. He was last heard from in May 1955, at which time he was in the United States Navy.

This fourteen-year-old boy had a dislocation of the atlas on the axis due without a doubt, in my opinion, to a congenitally separate odontoid process. It is interesting to note that the roentgenograms made in the next three cases appear similar to those in this case.

FIG. 3-A

FIG. 3-B

FIG. 3-C

Figs. 3-A and 3-B: Case 3. Lateral and antero-posterior views showing anterior dislocation of the atlas on the axis with a separate odontoid process. Note similarity to Figs. 2-A and 2-B although symptoms in this case commenced with trauma.

Fig. 3-C: Appearance nineteen months after cervico-occipital fusion and decompression of the spinal cord. The grafts have not fused distally and slight subluxation of the third on the fourth cervical vertebra is evident.

DISLOCATION OF THE ATLAS DUE TO SEPARATE ODONTOID PROCESS WITH A HISTORY OF TRAUMA

In the three cases of this type the patients' symptoms began with traumatic incidents that were probably contributory but not the true basis of the instability that resulted.

CASE 3. A nineteen-year-old boy reported to the clinic on July 19, 1949. One month previously, June 21, 1949, a fellow worker unexpectedly came up behind the patient and put his arm around the patient's neck, catching his throat in the crook of his elbow. The patient quickly flexed his body forward and with one movement he raised his fellow worker off the ground and tossed him over his head. The two fell to the ground, and the patient was unconscious. When he regained consciousness about two minutes later, his neck and the entire right and left upper extremities were numb. About fifteen minutes later, his neck became very painful and stiff. Roentgenograms made the day of the injury reportedly revealed a dislocation of the atlas on the axis, and the patient was fitted with a cervical collar which he wore until he reported to us. Roentgenograms made at the clinic revealed an anterior dislocation of the atlas on the axis and a short odontoid base with a separate process (Figs. 3-A and 3-B). The results of a neurological examination were negative.

On August 1, 1949, one of the neurosurgeons removed much of the posterior arch of the atlas together with the posterior rim of the foramen magnum. An orthopaedic surgeon then fused the spinal column from the occiput to the third cervical vertebra. Twelve days after surgical intervention, a plaster-of-Paris cast was applied and immobilization was continued for six months, then a cervical brace was applied and used for another six months. When the patient was last examined seven months later and nineteen months after the operation, fusion to the occiput was complete but only fibrous union had occurred distally. At this time also, slight secondary subluxation of the third cervical vertebra on the fourth was noted (Fig. 3-C). When last heard from, the patient was married and was working as a garage mechanic. He had not had further trouble with his neck.

CASE 4. A sixteen-year-old boy first registered at the clinic on September 25, 1956. At this time he

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: Case 4. Lateral and anteroposterior views showing slight posterior displacement of the atlas on the axis with a separate odontoid process presumably due either to a congenital anomaly or to an epiphyseal separation fourteen and one-half years before at the age of sixteen months. Note similarity to figures 2-A and 2-B.

Fig. 4-C: Appearance two months after decompression of the spinal cord and cervico-occipital fusion. Five months later there was still no evidence of fusion.

FIG. 4-C

complained of headaches, a stiff and painful neck, and attacks of dizziness, nausea, and vomiting. He reported that in 1941, at the age of sixteen months, he had fallen from a high chair and had landed on his head. Roentgenograms had reportedly revealed an abnormal relationship of the upper cervical vertebrae to the base of the skull. One year later his parents had noted that he did not walk in a straight position but seemed to lean to one side. In 1951, he began to have headaches in the bitemporal region. In 1952, it was noticed that he was holding his head to one side, and the neck had become painful. In April 1956, because of an attack of dizziness, nausea, and vomiting associated with headache, it was necessary for him to be hospitalized for five days. In September 1956, roentgenograms made at a well known clinic showed evidence of a separate odontoid process. Spinal puncture revealed a poor response of the cerebrospinal-fluid dynamics on Queckenstedt's maneuver, and the value for protein in the cerebrospinal fluid was seventy milligrams per 100 cubic centimeters. He was referred to the Mayo Clinic for treatment.

Roentgenograms made at the clinic showed a separate odontoid process and a slight posterior displacement of the atlas on the axis (Figs. 4-A and 4-B). On October 3, 1956, with the patient in an upright position, one of our neurosurgeons removed the middle portion of the posterior arch of the atlas for decompressive purposes and spine fusion was then performed from the occiput to the spinous process and lamina of the second cervical vertebra, with the use of previously removed iliac grafts. In placing the wire loop in the right side of the occiput, a small opening was inadvertently made in the dura mater. A few hours after operation the patient complained of numbness in the right leg and foot and an area of hypo-algesia was mapped out. On the following morning, hypo-algesia could not be detected, but there was weakness in dorsiflexion of the right foot. Three days later this weakness was no longer detectable. One week after the operation a plaster-of-Paris cast was applied. This was removed two months later and replaced with a brace. Roentgenograms made at this time did not reveal evidence of fusion of the grafts (Fig. 4-C). In February 1957, four months after the operation, he fell and struck his head. On April 23, 1957, almost seven months from the time of operation, roentgenograms still revealed evidence of non-union of the grafts. The patient was advised to continue to wear his brace in the hope that fusion still might occur. The patient stated that his headaches, although still present, were less severe than before the operation.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 6. Lateral view demonstrating marked anterior dislocation of the atlas on the axis as a result of a diving injury nine years previously. The odontoid process appears intact but short.

Figs. 5-B and 5-C: Pantopaque myelography showed a large defect at the level of the atlas and the axis.

FIG. 5-C

FIG. 5-D

Fig. 5-D: Appearance three and one-half months after cervico-occipital fusion.

CASE 5. A woman, thirty-six years old, first registered at the clinic on April 13, 1943, with a complaint of "loss of control of the feet for three years." She stated that in 1920, at the age of thirteen years, she was turning a somersault when she experienced a sudden, hot, prickly feeling in the face and fainted. The same symptoms recurred six months later when she quickly turned her head. A year and a half later, at the age of fifteen years, she first noted an unsteadiness of gait, and at twenty-nine, she noted the onset of occipito-frontal headaches. One year later her legs seemed to be stiff and like "stilts." At the age of thirty-three

years, or three years before coming to the clinic, she noted, during pregnancy, that her legs were numb and jerking. Neurological examination revealed that the patient walked with a spastic gait and hyperclonus was present. The biceps, triceps, supinator, patellar, and Achilles tendon reflexes were increased bilaterally. Hoffmann's sign and the Babinski reflex were positive. Roentgenograms, which unfortunately are no longer available, reportedly revealed a dislocation of the atlas on the axis with a separate odontoid process.

On May 15, 1943, with the patient in an upright position, a posterior decompression of the foramen magnum, atlas, and axis was performed and iliac grafts were wired to the occiput and the spinous process of the third cervical vertebra. After operation the patient was immobilized with a cervical brace for eleven months. The grafts partially absorbed and failed to fuse. When the patient was last examined in 1952, the neurological status was essentially the same as preoperatively, and it was felt that the patient had not received appreciable benefit from the surgical procedure.

Cases 3, 4, and 5 presented dislocation of the atlas on the axis due to short or separate odontoid processes. The roentgenograms in Cases 3 and 4 appear very similar to those in Case 2 in which the anomaly is almost certainly congenital in nature. Although the patient in Case 3 gave a history of significant injury to his neck, he was seen only one month later; the roentgenogram suggested an anomaly of the odontoid which had been present much longer than one month. The injury in Case 4 could have produced an epiphyseal separation of the odontoid as described by Blockey and Purser but, as they stated, one would expect union in such a separation. This statement further supports the hypothesis that the separate odontoid in Case 4 represented a congenital failure of fusion. The same would probably hold for Case 5. In this group of cases, as has been pointed out by McRae, symptoms which might be confused with those of brain tumor were present in two. The neurosurgeons were of the opinion that posterior decompression of the spinal medulla was indicated in Cases 2, 3, 4, and 5 and thus stabilization by cervico-occipital fusion was needed rather than fusion only from the atlas to the axis.

TRAUMATIC DISLOCATIONS AND FRACTURES OF THE ATLAS OR AXIS

In the next four cases it is my opinion that cervico-occipital fusions were performed for traumatic lesions without underlying congenital defects although I could not be sure about Case 6.

Case 6. A man, twenty-seven years old, reported to the clinic on October 29, 1951, because of pain in the neck together with numbness and tingling in the left upper and lower extremities. Nine years previously, at the age of eighteen years, he forcibly struck his head while diving, against the bottom of the pool and sharply flexed his head onto his chest. Immediately afterward, he experienced severe headache and dyspnoea. He soon recovered and did not experience further trouble until six months later following tonsillectomy and a throat infection. At this time stiffness and soreness with acute attacks of pain developed in the neck accompanied by numbness and tingling in the left upper and lower extremities.

Roentgenograms revealed a marked anterior dislocation of the atlas on the axis (Fig. 5-A). Whether or not the anterior body of the axis was wedged and whether the odontoid process was shorter than normal was not clear from the available roentgenograms. The results of neurological examination were normal, but for three to four days after pantopaque myelography which showed a large defect, the patient complained of tingling paraesthesia in his extremities (Figs. 5-B and 5-C). Traction by means of Crutchfield tongs failed to change the position and on November 21, 1951, a spine fusion, by means of multiple matchstick tibial grafts, was performed from the occiput to the second cervical vertebra. The tuberculum of the atlas was palpable in the depth of the wound but this was not exposed since it was displaced far anteriorly. Two weeks after operation a plaster-of-Paris cast was applied and immobilization was maintained for three months (Fig. 5-D). It was then continued for eight months by means of a brace. Roentgenograms at the end of this time showed firm fusion, and the patient, when last heard from, was working without complaints.

Case 7. A man, twenty-two years old, was in a severe automobile accident sixteen months before he reported to the clinic. He had sustained a rotatory dislocation of the atlas on the axis together with a fracture of the odontoid process (Figs. 6-A and 6-B) and also a marked fracture-dislocation of the fifth on the sixth thoracic vertebra (Fig. 6-C). For a week following the accident, he had been unconscious. He complained of pain in the neck, which had necessitated the wearing of a neck brace at all times. Neurological examination revealed minimal deficit. On April 7, 1953, a cervico-occipital fusion from the occiput to the fourth cervical vertebra was performed with iliac grafts. It was noted that the tuberculum of the atlas was rather markedly displaced to the right. A metal collar was used continuously for six months after the operation and was gradually discarded during the subsequent six months. Firm fusion from the occiput to the fourth cervical

FIG. 6-A

FIG. 6-B

FIG. 6-C

Fig. 6-A: Case 7. Anteroposterior view demonstrating a rotatory dislocation of the atlas on the axis.
Fig. 6-B: Laminogram (tomogram) demonstrating the dislocation, an apparent old fracture of odontoid process with malunion. Note displacement to the right.
Fig. 6-C: Anteroposterior view of the thoracic spine shows an associated fracture-dislocation of the fifth on the sixth thoracic vertebra.

FIG. 6-D

FIG. 6-E

Figs. 6-D and 6-E: Lateral views showing flexion and extension eleven months after cervico-occipital fusion. No motion could be demonstrated beneath the grafts.

vertebra resulted, as was proved by roentgenograms made with the neck in flexion and extension (Figs. 6-D and 6-E). When last examined in March 1954, one year after the fusion, the patient was attending college and stated that he no longer experienced pain in his neck.

CASE 8. A seventeen-year-old girl sustained a fracture-dislocation of the second on the third cervical vertebra with locked facets two months before she reported to the clinic. The results of neurological examination were negative. At the time of operation it was noted that the ligamentum flavum between the first and

FIG. 7-A

FIG. 7-B

Figs. 7-A and 7-B: Case 9. Lateral and anteroposterior views of an ununited fracture of the odontoid with slight anterior dislocation of the atlas on the axis.

Fig. 7-C: Appearance nine months after cervico-occipital fusion.

FIG. 7-C

second cervical vertebrae had been ruptured. Because of the exposed dura, it was decided to bridge the ruptured portion with grafts which were fastened proximally to the occiput and distally to the fourth cervical vertebra. A few days after operation it was necessary to release a hematoma. The patient momentarily lost consciousness and became incontinent of urine. By the next morning urinary control had returned, and there was no evidence of sensory or motor deficit in the extremities. The patient was immobilized with a plaster-of-Paris cast for four months and with a brace for the subsequent four months. Roentgenograms made at this time showed evidence of fusion from the occiput to the second, third, fourth, and fifth cervical vertebrae. In a recent communication, the patient reported that she was completely comfortable. She estimated that she had lost about 30 per cent of neck motion but that this did not interfere with her daily activities. She stated that when she drove a car, she found it much easier to use a mirror rather than to turn her body.

CASE 9. A man, twenty-six years old, sustained a fracture of the odontoid process in an airplane crash eight months before reporting to the clinic. He had been immobilized in a plaster-of-Paris cast for six months but the fracture had failed to unite (Figs. 7-A and 7-B). He was a rancher and a stockman and because of this rather hazardous occupation spine fusion was advised. A cervico-occipital fusion was performed on January 18, 1948, by means of iliac grafts. Because of slight anterior displacement of the atlas on the axis, beds were prepared for the grafts only on the occiput and the second cervical vertebra. He was immobilized in a plaster-of-Paris cast for six months and a brace for three months when union of the grafts was noted on roentgenographic examination (Fig. 7-C).

The relationship of the throat infection to the secondary onset of symptoms in Case 6 is interesting and debatable. One wonders whether it was necessary to include the occiput in the fusion in Cases 8 and 9, but at the time of operation this was judged to be the safest course to follow and both patients obtained satisfactory results.

COMMENT

Two patients had congenital anomalies which resulted in instability of the atlas on the axis. Although histories of trauma were given by three patients whose roentgenograms showed evidence of a separate odontoid process with dislocation of the atlas on the axis which closely resembled that in Case 2, it is probable that dislocation and subsequent symptoms would not have occurred had the odontoid and perhaps the associated ligaments developed normally. In Case 1 the deformed axis was congenitally fused to the occiput and in the other four of these five cases surgical decompression of the spinal cord whereby much of the posterior arch of the axis was excised was deemed necessary by the neurosurgeons who cooperated in the care of all patients. Thus fusion to the occiput was necessary in these five patients.

The remaining four patients, having cervico-occipital fusion because of dislocation or instability of the upper cervical vertebrae, gave histories of severe trauma to the neck. In at least one and possibly two of these patients fusion from the first to the third cervical vertebra might have sufficed, but at the time of operation, because of extenuating circumstances, it was deemed best to fuse to the occiput and bypass the unstable atlas. It should be emphasized that the majority of patients with congenital or post-traumatic anomalies of the atlas or axis do not require fusion to the occiput. The cervico-occipital fusion is necessary only when an extensive posterior laminectomy is required or in the occasional instance when the atlas is far anterior and cannot be safely reduced. No attempt has been made in this paper to include those patients who have had fusion of only the first and second or perhaps of the first three cervical vertebrae. The fusion was carried distally one or two cervical segments farther than was probably necessary in three patients. In one of these patients fusion to the occiput occurred but not to the cervical vertebra. Nevertheless, one year later roentgenograms showed slight subluxation of the third on the fourth cervical vertebra, probably as a compensatory mechanism. In one patient, a child with a marked congenital anomaly, symptoms were initiated by mumps and were brought on again several years later by an upper respiratory infection. Another patient who was injured in a diving accident experienced the onset of lasting symptoms six months later after tonsillectomy followed by a throat infection.

Whether the patient was prone or in an upright position during the surgical procedure seemed to make little difference. Visualization was better when the upright position was used since blood did not tend to collect in the wound. All grafts were wired in position except the tibial matchstick grafts used in one patient; complete fusion occurred in this patient.

Pseudarthrosis developed in three of the four patients who had decompression procedures. The posterior margin of the foramen magnum in two, much of the posterior arch of the atlas in three, and much of the posterior arch of the axis in one were removed. Iliac grafts were used in two patients and a tibial graft was used in one of the three patients who had pseudarthrosis. Iliac grafts were used in three and tibial grafts in three of the six patients whose grafts fused to the occiput and to the vertebrae.

One of the patients in whom fusion developed after the use of tibial grafts and who was immobilized for the shortest period was a ten-year-old child. The average period of immobilization postoperatively was nine months. Two patients had a temporary increase in neurological deficits after operation. One of these patients had had decompression of the spinal cord and the other had not.

SUMMARY AND CONCLUSIONS

Since 1943, nine patients have had cervico-occipital fusion performed at the Mayo Clinic. Two patients had definite congenital anomalies, three had roentgenographic evidence of a separate odontoid process with dislocation of the atlas on the axis, and four had dislocation or instability as a result of severe trauma to the neck. In most cases the technique of Cone and Turner was used, with modifications. Fusion to the occiput and to the vertebrae resulted in six of the nine patients.

The study of these cases has led to the conclusion that many patients who have had a diagnosis of an ununited fracture of the odontoid with dislocation of the atlas on the axis actually have had a congenital anomaly of the odontoid and possibly a congenital anomaly of the associated ligaments. It also seems probable that patients in whom spontaneous dislocation of the atlas develops in conjunction with an infectious process may be more susceptible to such dislocation because of an underlying congenital or post-traumatic anomaly of the odontoid process and the neighboring ligaments.

Cervico-occipital fusion is successful in the majority of cases. It is more likely to result if extensive posterior decompression of the spinal cord is not necessary. However, if such decompression is not necessary, fusion of only the first and second cervical vertebrae is usually required. Prolonged immobilization of the head and cervical portion of the spinal column, preferably with a brace, until the wound is healed and then with either a Minerva or Calot type plaster-of-Paris cast followed again by the brace for a total of six to twelve months, is necessary for cervico-occipital fusion. The limitation of motion resulting from fusion of the occiput to the axis is hardly missed by the average person.

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Oblique Roentgenographic Views of the Cervical Spine in Flexion and Extension

An Aid in the Diagnosis of Cervical Subluxations and Obscure Dislocations *

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Subluxation of the cervical spine following acute trauma, as in automobile accidents, is a frequent roentgenographic finding. Treatment has in many instances been discouraging because of recurrence of the subluxation after traction and immobilization.

Of considerable significance is the anatomical lesion responsible for the roentgeno-

FIG. 1-A

FIG. 1-B

graphic appearance. Davis, in his detailed description of lesions of the spine, classified the subluxation group as obscure. He had attempted, by means of lateral roentgenograms made with the spine in flexion and in extension, to determine the anatomical basis for subluxation. Functional roentgenography appeared to be a logical approach.

It has often been noted that in a case in which there has been acute trauma or in which there are multiple injuries, recognition of the subluxation is delayed. In the meantime, the patient may have received general anaesthesia with no visible untoward effects. It can, therefore, be assumed that in such cases, after careful clinical and roentgenographic examination, including routine oblique views to rule out obvious lesions, it would be safe, under the supervision of a physician, to make functional roentgenograms of the cervical spine.

In October 1952, such a case was seen in an emergency ward. The patient was smoking

* This material was presented in the form of a Scientific Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23 to 28, 1954, and the Annual Meeting of the Radiological Society of North America, Los Angeles, California, December 1954.

FIG. 2-A

FIG. 2-B

FIG. 2-C

FIG. 2-D

a cigarette and walking around. An attempt was made to obtain a lateral roentgenogram with the spine in flexion and extension, but because of muscle spasm an oblique view with the spine in flexion and extension was obtained instead. It was immediately evident from this projection, which had never previously been used in this type of case, that a unilateral subluxation was present.

The most satisfactory technique of obtaining this view is to place the Bucky diaphragm in an upright position with the patient either standing or sitting. The patient's head is rotated maximally to the right, the left side being against the Bucky diaphragm

FIG. 3-A

FIG. 3-B

FIG. 3-C

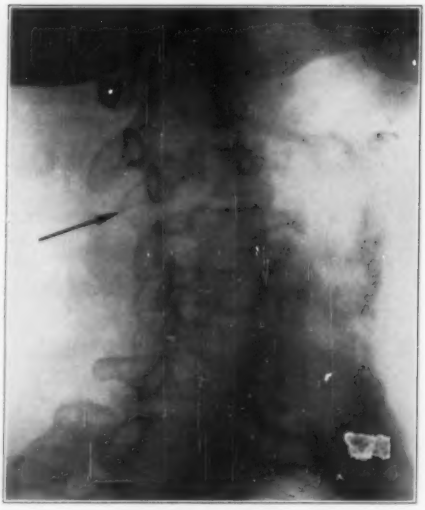

FIG. 3-D

(Figs. 1-A and 1-B). The chin is then flexed toward the right shoulder, care being taken to maintain maximal rotation of the cervical spine, and the head is extended, full rotation being maintained. The tube is set in the position for making a postero-anterior roentgenogram of the chest or a lateral roentgenogram of the skull but is centered over the cervical spine. The body is not rotated; both shoulders are held firmly against the Bucky diaphragm.

To demonstrate the mechanics of this view the image-amplifier fluoroscope is used. As a result of the patient's head being rotated to the right, the posterior elements of the left side of the spine are shown in profile. As a result of the rotated neck being flexed, the articular processes are also shown in profile and the apophyseal joints are opened to the maximum degree. This method gives one an opportunity to examine the ligamentous structures under stress on one side at a time. Also, it demonstrates fractures of the articular processes and other posterior elements, the fragments being actually displaced. A view of the intervertebral foramina in a wide-open position is obtained.

FIG. 3-E

This technique is valuable in demonstrating obscure lesions of the cervical spine in the same manner that stress roentgenograms demonstrate tears of the collateral ligaments of the ankle and knee. In cases of traumatic injury, when subluxation is not shown by the lateral and normal oblique roentgenograms made with the spine in flexion and extension, this technique will allow a more positive diagnosis of acute sprain of the cervical spine.

In each of the following cases presented, the findings have been verified at operation.

CASE 1. J. B., a woman, twenty-four years old, was admitted to Jefferson Davis Hospital on October 19, 1952, having been in an automobile accident that day. The automobile in which she was riding had struck the rear of a parked vehicle. She had a small laceration on the mid-forehead at the hair line. The head was tilted to the left and the chin was rotated to the right.

Routine films of the cervical spine revealed only a straight cervical spine with minimal malalignment of the sixth and seventh cervical vertebrae in the lateral view. Oblique roentgenograms in flexion and extension revealed the inferior facet of the sixth cervical vertebra subluxated in relation to the superior facet of the seventh cervical vertebra on the left (Figs. 2-A through 2-D) in flexion and returning into approximation on extension. The right oblique roentgenograms made in flexion and extension revealed normal relationships at the apophyseal joints.

Crutchfield tongs were applied to the skull, and the patient was placed on a Stryker frame. Nine pounds of weight was used for traction for a period of six weeks. There was some weakness of the long flexors of the left hand only. A plaster cast with head piece was applied and worn until March 23, 1953. Oblique roentgenograms made in flexion and extension revealed continued alteration of the apophyseal joint between the sixth and seventh cervical vertebrae with apparent failure of conservative treatment.

The patient had progressively more neck pain and complained of numbness in the tips of all fingers.

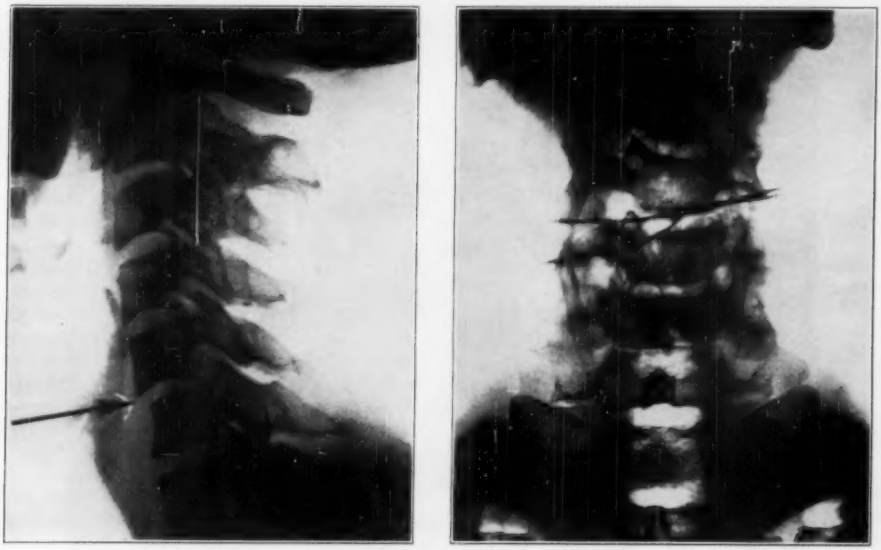

FIG. 4-A

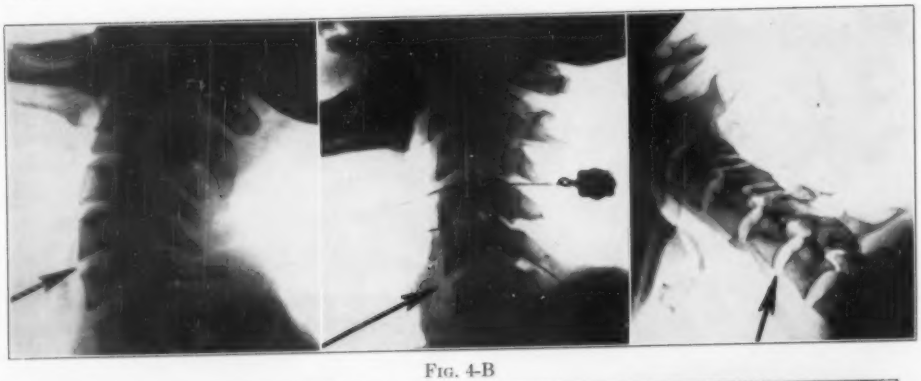

FIG. 4-B

FIG. 4-C

FIG. 4-D

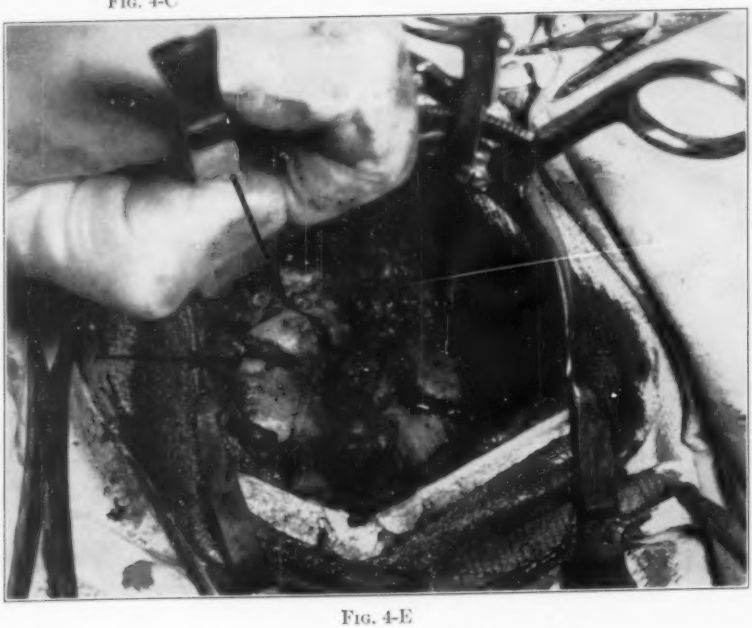

FIG. 4-E

FIG. 5-A

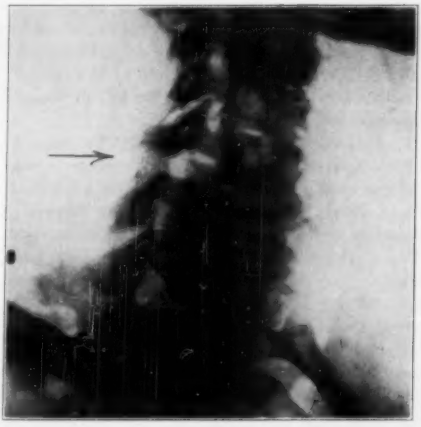

FIG. 5-B

FIG. 5-C

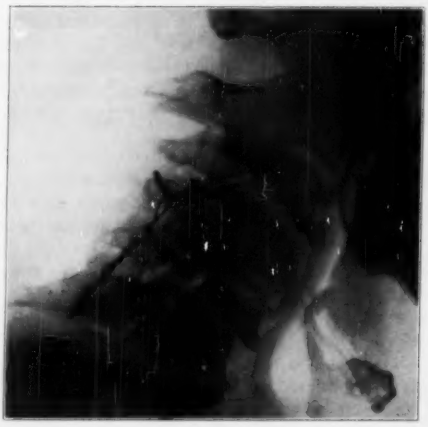

FIG. 5-D

She was completely unable to work. Oblique films in flexion and extension made on August 31, 1953, demonstrated the alteration of the apophyseal joint between the sixth and seventh cervical vertebrae on the left still present as on the date of accident.

An open reduction of the cervical spine was performed under local block anaesthesia on September 12, 1953, with the patient sitting erect on the regular operating table and the head in the cervical laminectomy attachment. The spinous processes were grossly in good alignment. Old ruptures of the interspinous ligament and ligamentum flavum on the right at the sixth and seventh cervical vertebrae were found with no evidence of repair. The posterior capsule of the apophyseal joints at the sixth and seventh cervical vertebrae were removed. No evidence of old fracture of the facets could be identified. The facets on the right were in normal anatomical relationship. The inferior facet of the sixth cervical vertebra on the left was forward on the superior facet of the seventh cervical vertebra about one centimeter. In other words, the inferior facet of the sixth cervical vertebra was subluxated forward and could not be reduced in normal relationship with the superior facet of the seventh cervical vertebra. The spinous processes of the fifth, sixth, and seventh cervical vertebrae were wired together and iliac grafts were applied over the laminae. The patient was last seen in the clinic on August 5, 1954, at which time fusion was solid. She was working full time as an interior decorator.

CASE 2. F. S., a man, forty-eight years old, was admitted to Jefferson Davis Hospital on August 16, 1953, with multiple injuries following an accident in which his automobile ran off the road and turned over. His complaints of neck pain were minimal. Routine cervical spine views revealed a straight spine and only minimal malalignment of the third and fourth cervical vertebral bodies (Fig. 3-A). There was no evidence of fracture. The resident staff felt that the injury was not serious and required no treatment.

Examination five days after admission revealed only minimal restriction of right lateral flexion and right lateral rotation. The neurological examination was within normal limits. According to the patient he had neck pain only for the first few days. Oblique roentgenograms made in flexion and extension (Figs. 3-B through 3-E) revealed what appeared to be a complete dislocation at the apophyseal articulation of the third and fourth cervical vertebrae on the left in flexion. In extension it appeared to have returned to almost normal position.

Under local block anaesthesia, with the patient sitting erect in the laminectomy frame, open reduction was performed on August 25, 1953. The spinous processes of second and third cervical vertebrae were to the left of the midline about three-eighths of an inch. This had not been demonstrable in the anteroposterior roentgenogram. The interspinous ligament between the third and fourth cervical vertebrae was completely ruptured as was the ligamentum flavum on the right. The dura was visible. There was a transverse fracture of the superior half of the articular facet of the fourth cervical vertebra and of the inferior half of the facet of the third cervical vertebra on the left with complete displacement. The apophyseal joint of the third and fourth cervical vertebrae on the right was dissected out and found to be intact. The head rest was removed and the patient was allowed to flex and extend the cervical spine while the surgeon observed the apophyseal joints. With the chin to the right as in the position for making a left anterior oblique roentgenogram, the remaining intact portions of the facets which were transverse, approximated, but did not reduce in extension, and were separated in flexion. This explained why in the original left oblique roentgenograms made in extension the left inferior articular process of the third cervical vertebra appeared to engage the superior process of the fourth cervical vertebra and in flexion appeared to dislocate forward. In neutral rotation flexion and extension altered the fracture surfaces little, if any. To actually reduce the fracture-dislocation, the spinous processes of the second and third cervical vertebrae were moved as a segment up, over, and to the right with a towel clip. The relationship was quite stable and the patient by flexing and extending the cervical spine could not redislocate the apophyseal joint. The spinous processes of the second, third, and fourth cervical vertebrae were wired and iliac grafts placed over the laminae. The fusion was solid when roentgenograms were made in February 1954. At that time, the patient was working full time on a farm.

Case 3. R. L., a forty-year-old man, was admitted to the Veterans Administration Hospital, Houston, Texas, about one hour after an automobile collision on December 1, 1953. On admission to the hospital, he complained of headache and posterior neck pain. The findings on physical examination were not remarkable except for an eight-centimeter laceration on the left aspect of the forehead. There was extreme muscle spasm about the cervical spine. Roentgenograms of the cervical spine made on admission were poor. He was placed in cervical head traction. Better quality roentgenograms including routine oblique and lateral roentgenograms made in flexion and extension (Figs. 4-A and 4-B) revealed a subluxation of the fifth on the sixth cervical vertebra only in the lateral projection. Oblique views in flexion and extension were made on December 13, 1953, revealing a fracture of the articular process of the fifth cervical vertebra on the left (Figs. 4-C and 4-D). Operation was performed as previously described with the patient erect under local block anaesthesia on December 21, 1953. There was a fracture of the articular process of the fifth cervical vertebra on the left. The fracture surfaces were displaced only by rotating the head to the right and flexing the chin toward the right shoulder (Fig. 4-E). There was no ligamentous tear or joint-capsule tear in this case. Cervical fusion was carried out. One month following surgery, the patient, wearing a metal-type Thomas collar, returned to work as a short-order cook. On May 20, 1954, roentgenograms revealed a solid fusion. He was last seen on June 17, 1955, and stated that he had no discomfort in the neck.

Case 4. R. C. G., a man, fifty-seven years old, was in an automobile collision on June 16, 1953, in which he was thrown out of the car onto the road. Roentgenographic diagnosis in a distant hospital was degenerative arthritis with no bone or joint injury. A second study was done on September 22, 1953, in which lateral roentgenograms revealed only degenerative arthritis of the cervical spine. Left oblique roentgenograms (Figs. 5-A and 5-B) made in flexion showed a unilateral rotatory dislocation of the fifth on the sixth cervical vertebra. This was confirmed at operation on October 19, 1953, at which time the spinous processes of the fourth, fifth, and sixth cervical vertebrae were wired together and bone grafts were placed across the gaps between the neural arches. Roentgenograms (Figs. 6-C and 6-D) made eight weeks later in maximum flexion and maximum extension show solid bone union. The patient is now symptom-free and has resumed his occupation as a diemaker.

CONCLUSIONS

1. A technique of functional roentgenography of the cervical spine is described as an aid in establishing an anatomical diagnosis of subluxations and obscure dislocations.

2. Four cases are presented with roentgenographic and operative findings: (a) marked unilateral apophyseal joint subluxation; (b) unilateral fracture-dislocation; (c) unilateral fracture of the articular process; and (d) minimal unilateral apophyseal-joint subluxation.

3. It is suggested that the ligamentum flavum is important in the stability of the cervical spine.

4. Obscure anatomical lesions of the cervical spine are best demonstrated at operation with the patient awake and sitting on the regular operating table, the laminectomy head rest being used.

A Technique for Femoral-Shaft Shortening

A Preliminary Report

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The purpose of this paper is to describe a technique for mid-shaft shortening in which a predetermined guide, an intramedullary rod, and onlay bone grafts are used. It was found to be technically simple and has proved successful in two cases.

Thompson, Straub, and Campbell, in 1954, reported forty cases in which femoral-shaft shortening was obtained by oblique osteotomy and eleven cases in which shortening was obtained by transverse osteotomy with intramedullary Küntscher-nail fixation. They favored the former method and gave as their reasons that fewer secondary operations were required (removal of the nail was listed as a secondary operation) and that there were less complications (bent nail, one case; broken nail, one case; genu recurvatum, four cases; loss of full extension by six months after the operation, one case; and non-union, one case). The first two complications were due to mechanical weaknesses of the nail; the genu recurvatum was due to too early mobilization and to not allowing time for muscle tone to be regained. The non-union occurred in Case 7, in which there was a bent nail. After eight months all of the patients, with the exception of the patient in Case 7, had solid bone union and were walking unsupported.

It is not the purpose of this paper to review the literature on femoral-shaft shortening, as it is well known. It suffices to note that the techniques most commonly used in the past have been either subtrochanteric or supracondylar osteotomy combined with blade-plate fixation. King, in 1945, pointed out that osteogenesis is delayed in the trochanteric or condylar areas of the femur; this view is not supported by others, however. In 1949, White, in the discussion of Thornton's paper, stated his preference for shortening the femur through the mid-third of the shaft of the bone; in a series of five or six cases, he had had two instances of delayed union and one of non-union as a result of using the subtrochanteric method. Intramedullary nailing is most successful in the mid-third of the shaft and hence this is the site of choice for the technique to be described. Four inches of bone is the maximum amount that can be removed.

If a predetermined non-movable guide is used, accurate refitting of a large bone surface is assured and error in the degree of rotation and in the amount of bone removed is avoided. If one-half of the removed bone is used as an onlay graft and secured with two or four screws, distraction is prevented; use of the other one-half of the removed bone as onlay chips helps osteogenesis. It is logical that following any type of shortening, the extremity should be immobilized, either in a cast or in some type of suspension, in order

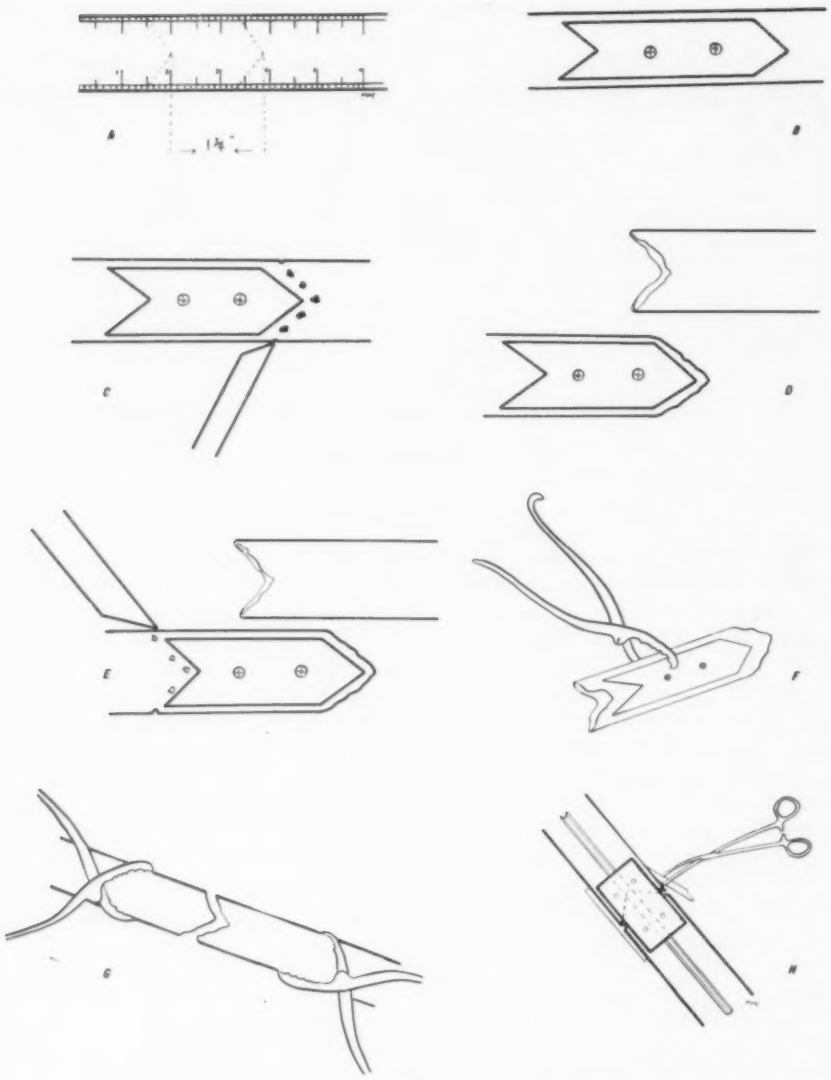

FIG. 1

Drawing illustrating the steps used in femoral-shaft shortening.

to allow muscle tone to be re-established. This is important because the muscles help support the femur and impact the fragments. Distraction, angulation, and genu recurvatum can be expected to occur if this step is overlooked. Four to six weeks is the usual length of immobilization. After this period or when callus is observed, ambulation may be started. Both patients reported in this paper were bearing full weight in eight weeks and had solid bone union in four to six months.

TECHNIQUE

The amount of bone to be removed is determined preoperatively and an ordinary surgical ruler is cut with parallel V's so that the chevron points are one-quarter of an

FIG. 2-A

Fig. 2-A: Case 1. Anteroposterior and lateral roentgenograms of the left femur made seven and one-half weeks after the operation. Note the beginning union and callus formation. The patient was weight-bearing at this time.

Fig. 2-B: Anteroposterior and lateral roentgenograms of the left femur showing complete union thirteen months after the operation.

FIG. 2-B

inch shorter than the amount of bone to be removed (Fig. 1, *A*). (Haas was the first to use the technique of shortening the femur by means of parallel chevron-shaped osteotomy cuts.) The ruler is then perforated for fixation with screws seven-sixty-fourths of an inch in diameter.

The mid-shaft of the bone is exposed through an anterolateral incision and the guide is secured to the mid-shaft by screws (Fig. 1, *B*). An osteotomy is done at one end of the guide by means of either multiple

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2. Anteroposterior and lateral roentgenograms of the right femur made four weeks after the operation, showing beginning callus formation. At this time the patient began weight-bearing.

Fig. 3-B: Anteroposterior and lateral roentgenograms of the right femur made sixteen months after the operation, showing complete union. The intramedullary rod has been removed.

drills and an osteotome or a Gigli saw, although use of the latter is difficult (Fig. 1, *C*). A power tool is avoided because of burning. The bone is then separated (Fig. 1, *D*). Error in the degree of rotation or in the length of bone to be removed is impossible because the guide remains securely fixed to the fragment through which the second osteotomy is done (Fig. 1, *E*). The piece of bone removed is one-quarter of an inch longer than the guide because of the extra space required to perform the osteotomies (Fig. 1, *F*). The fragments fit accurately when reduced, rotational error thus being prevented (Fig. 1, *G*). An intramedullary rod is inserted in the retrograde manner (clover-leaf nails are used), and the fragments are reduced. One-half of the removed bone is used as an onlay graft and is secured with two or four screws placed in the cortex of the femur, distraction being thus prevented. The remaining bone is used as onlay chip grafts (Fig. 1, *H*).

The patient is kept at rest, either in a cast or in suspension, for at least four weeks to allow muscle tone to be regained and callus formation to begin before weight-bearing is permitted. Both patients were bearing full weight at eight weeks and union was secure in twelve weeks. The rod was removed from one of these patients; the other is asymptomatic after a year.

CASE 1. J. R., a thirteen-year-old girl, was seen initially in May 1954, at which time it was noted that she had congenital abnormalities of the right lower extremity. The fifth toe and metatarsal ray, the lateral cuneiform, the navicular, and the cuboid were absent, and there was fusion of the talus and calcaneus. There was a two-inch shortening of the involved extremity, so that she was five feet, two inches when standing on the short limb and five feet, four inches when standing on the normal limb.

On June 29, 1954, femoral-shaft shortening was carried out on the left lower extremity, the previously described technique being used. The limb was immobilized for four weeks in a single spica cast; following this she began to bear weight on crutches. Roentgenograms made seven and one-half weeks after the operation showed considerable callus (Fig. 2-A); at this time she assumed full weight-bearing. Twelve weeks after the operation union was nearly complete, as noted in the roentgenograms; and thirteen months after the

operation the roentgenograms showed complete union with further trabeculation of the bone (Fig. 2-B). At this time she was five feet, two inches tall when standing on either limb. No complications in locomotion were noted as a result of the surgery.

CASE 2. S. L. C., a fourteen-year-old girl, was first seen by Dr. F. O. McGehee on November 20, 1944, because of a congenital dislocation of the left hip which was first noted when she was three months old. Treatment was advised, but the parents refused. The patient was seen again in 1951, at which time it was noted that the left lower extremity was two and three-quarters inches short. A false acetabulum had formed, and traction and arthrotomy were advised but refused. Stapling was done on the distal femoral epiphysis of the opposite limb. On July 7, 1955, the limb-length discrepancy was still two and three-quarters inches. Femoral-shaft shortening was performed on the right limb, since the function of the left hip with the false acetabulum was satisfactory. She remained in suspension four weeks after the operation and began to bear weight on crutches at the end of this time. Roentgenograms at this time showed beginning callus formation (Fig. 3-A), which was complete at six months. The rod was removed February 23, 1956 (seven months after the operation); and on November 24, 1956 (sixteen months after the operation), roentgenograms showed continued trabeculation and incorporation of the graft (Fig. 3-B). The patient was five feet tall when standing on either limb and had no complications in locomotion as a result of the surgery.

SUMMARY

The operative procedure described for femoral-shaft shortening avoids the complications of angulation, fracture of the nail, and genu recurvatum by allowing four weeks' postoperative immobilization of the limb either in a cast or in suspension. It also avoids error in degree of rotation and in the amount of bone removed by the use of a predetermined guide, and it avoids distraction by the use of an onlay graft secured with screws. The technique has proved to be simple and effective in the two reported cases.

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Sarcoma in Paget's Disease of Bone *

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In 1877, Sir James Paget thoroughly described a disease which he called osteitis deformans, but which since has been commonly called Paget's disease of bone. He discussed five cases, in two of which the disease was complicated by sarcoma. Paget later presented seven additional uncomplicated cases [38] and, in 1889, reviewed his total experience with twenty-three cases of osteitis deformans [39]. Eight of the patients had died, five from malignant lesions, a fact which impressed Paget that there might be some predisposing factor in these patients for malignant disease. Other examples of Paget's disease of bone complicated by sarcoma soon were presented. Goodhart and Howse each described a case in 1878. Wherry in 1894 presented a case in which sarcoma in Paget's disease developed at the site of a fracture of the distal portion of the tibial shaft which the patient had incurred three months previously.

Packard, Steele, and Kirkbride, reviewing the literature in 1901, found that in 7.5 per cent of sixty-seven cases of Paget's disease sarcoma had developed. In 1927, Bird reviewed sixty-four cases of Paget's disease found in Boston hospitals, including seven with sarcoma, an incidence of 11 per cent. Pike noted four sarcomata in his series of fifty-three cases of Paget's disease, and Lake found a 5 per cent incidence. Rosenkrantz, Wolf, and Kaicher found that 7.2 per cent of their 111 patients with Paget's disease had sarcoma.

Analyzing data in seventy-one cases of osteogenic sarcoma in which the patients were more than fifty years of age, Coley and Sharp reported that 28 per cent were associated with Paget's disease. In addition, 60 per cent of the osteogenic sarcomata of the tibia, humerus, and ilium and 100 per cent of those of the skull in this age group were in patients with pre-existing Paget's disease. Kolodny found that 5 per cent of all osteogenic sarcomata, regardless of the age of the patient, in the Bone Sarcoma Registry material had arisen in Paget's disease.

Summey and Pressly collected data on seventy-three cases of sarcoma complicating Paget's disease and added three of their own. They found that the average age was 57.7 years with a range from thirty-two to seventy-eight years; 84 per cent of these patients were men and 16 per cent were women. Twenty-six of the seventy-six patients had sarcoma in more than one area and were assumed to have multiple, primary, malignant tumors. In 1912, Gruner and associates described histological characteristics that in their opinion allowed differentiation between primary and metastatic sarcomatous lesions in Paget's disease. In their primary lesion, there was a transition from osteosclerotic bone to cellular sarcomatous tissue, while the metastatic nodules were sharply demarcated from surrounding bone. It has been noted [25], in bone affected by sarcoma in Paget's disease, that marrow in areas away from the sarcoma may contain cellular stroma with large spindle cells, a condition considered to be presarcomatous.

Most of the reports on Paget's disease and complicating sarcoma have dealt with small numbers of cases, and conclusions from such series taken singly have relatively

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little value. Accordingly, data on all cases from the English-language literature were collected in the course of this study[1-8,10,11,14-24,26,27,29-31,33-37,39-45,47-56]. These will be analyzed in a later section of this paper.

MATERIALS AND METHODS

This study includes all of the cases of bone sarcoma complicating lesions diagnosed roentgenographically as Paget's disease which were seen at the Mayo Clinic prior to January 1956. To locate these cases, records of 1,753 patients who had Paget's disease were reviewed. The age, sex, and alkaline phosphatase levels of these patients with Paget's disease were recorded. All follow-up records of these patients were also reviewed and, if the patient was dead, the cause of death was noted. Only cases in which the sarcoma was obviously of osseous origin were included in this study.

Ten cases of sarcoma arising in bone, proved by biopsy, and occurring in Paget's

TABLE I

AGE DISTRIBUTION

Age (*Years*)	Paget's Disease (*No.*)	Paget's Disease (*Per Cent*)	Paget's Disease with Sarcoma (*No.*)	Paget's Disease with Sarcoma (*Per Cent*)
20–29	3	0.2	0	0
30–39	60	3	1	1
40–49	268	15	16	15
50–59	638	37	34	33
60–69	565	32	41	39
70–79	202	12	9	9
80–89	17	1	3	3
Total	1,753		104	

disease were found; six other cases were also found which were probably sarcoma. The biopsy specimens in the ten patients had been removed at the clinic, and the microscopic slides and the tissue, preserved in 10 per cent formalin, were available for review. In an eleventh case, postmortem examination had been performed elsewhere, and the report of the necropsy, but no tissue, was available for study. Four of the ten with available tissue for review had undergone amputations at the clinic and the entire specimens were available. In five cases with no tissue to study the diagnosis was established by critical analysis of the clinical course and the roentgenograms.

Four of the sixteen cases have been reported previously[7,16,21].

CLINICAL FINDINGS

Incidence

In 1921, Carman and Carrick reported an incidence of fifteen cases of Paget's disease in 237,000 registrations at the Mayo Clinic, or roughly one in 16,000 patients. The incidence in the last six years has been one in 900 registrations. The increase is explained chiefly by the increased use of diagnostic roentgenography with resultant detection of more preclinical Paget's disease.

In the files of the clinic through 1955, records were found of 1,753 patients with Paget's disease of bone. Among these, sixteen were found to be complicated by sarcoma, giving an incidence of 0.9 per cent.

No attempt was made to follow the patients with Paget's disease not complicated by sarcoma. Follow-up reports on the records of these patients, however, reveal that 121 patients are known to have died and only one, not included in this report, was considered to have died of sarcoma complicating Paget's disease.

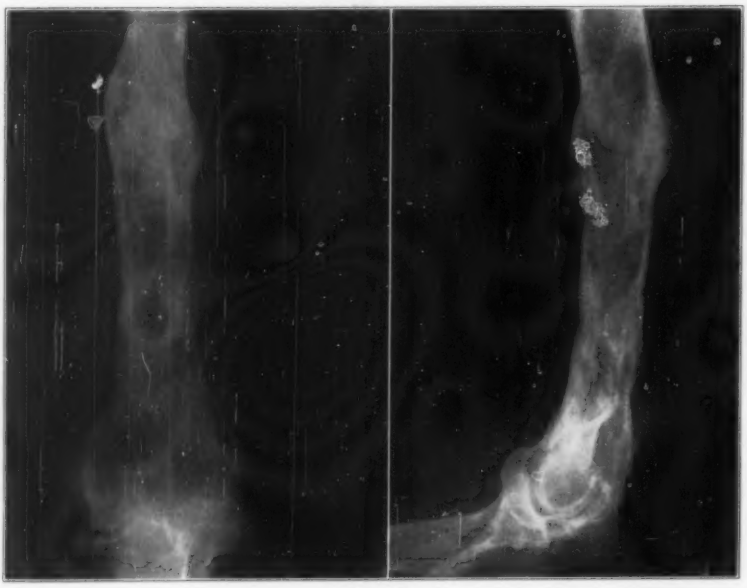

FIG. 1-A

Case 16. Distal portion of the left humerus with Paget's disease three months after fracture. The healed fracture site can be seen at the junction of the middle and the distal thirds of the shaft.

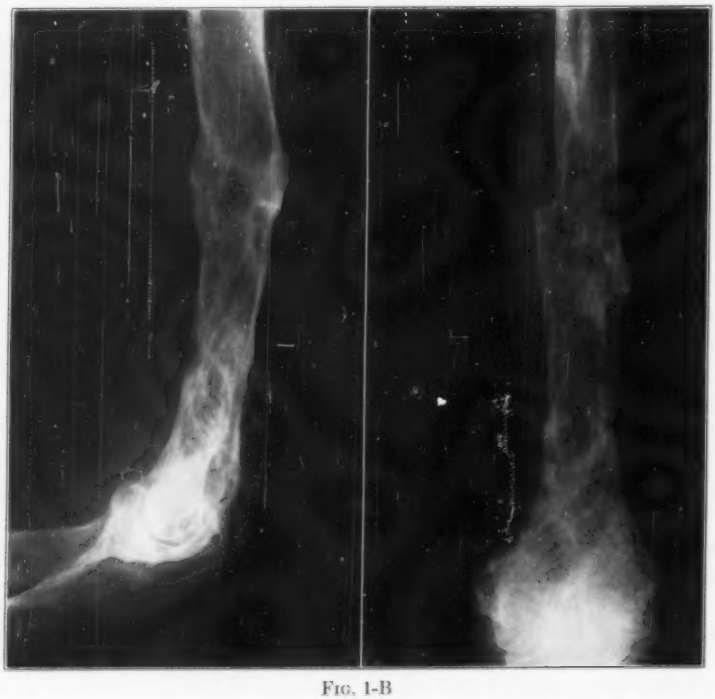

FIG. 1-B

Roentgenograms made five months later. Pain and swelling above the left elbow have been present for two months. Roentgenograms interpreted as showing Paget's disease.

Age

The ages of 1,753 patients with Paget's disease ranged from twenty-two to eighty-seven years, with an average of 58.1 years. These ages were those at the time when the diagnosis of Paget's disease was made at the clinic, and no determination of the age distribution at the time when symptoms began was made. The age distribution is shown in Table I.

The ages of the sixteen patients with sarcoma complicating Paget's disease ranged from thirty-two to seventy-two years (Table II). The average age was fifty-eight years, and the median age was fifty-nine years. The distribution is as follows: thirty through thirty-nine years, one case; forty through forty-nine years, one case; fifty through fifty-nine years, six cases; sixty through sixty-nine years, six cases; seventy through seventy-nine years, two cases.

Sex

The patients with Paget's disease presented a sex ratio of 1,154 men to 599 women, or roughly two to one. There were eleven men and five women with sarcoma complicating Paget's disease in this series.

FIG. 1-C

Roentgenogram made at time of admission another five months later. The sarcoma is now obvious and metastatic growths are present.

Signs and Symptoms

Severe, local pain was present in every case of sarcoma except one, and it was generally the chief complaint. Seven patients also had radiating pain, a symptom which indicated involvement of peripheral nerves.

A tumor mass was palpable in every instance. In six cases the patients had not previously noted a mass, while in four cases it was at least a part of the chief complaint. Dilated veins were noted over three of the tumors, and five patients had some degree of swelling of the extremity distal to the neoplasm. A limp was observed in five of the patients.

The duration of symptoms had varied from one to eight months, with an average of 4.5 months. Twelve of the patients previously had sought medical aid, but the diagnosis had not been established. In a thirteenth patient, the only one who had had no pain, treatment was delayed because amputation had been refused.

Only two of the sixteen patients were aware that they had Paget's disease at the time when they presented themselves with sarcoma. One of these had had Paget's disease for ten years and the other for two years. Two other patients, in retrospect, had had symptoms of Paget's disease for ten and fifteen years, respectively. The other twelve patients did not know that they had Paget's disease of bone.

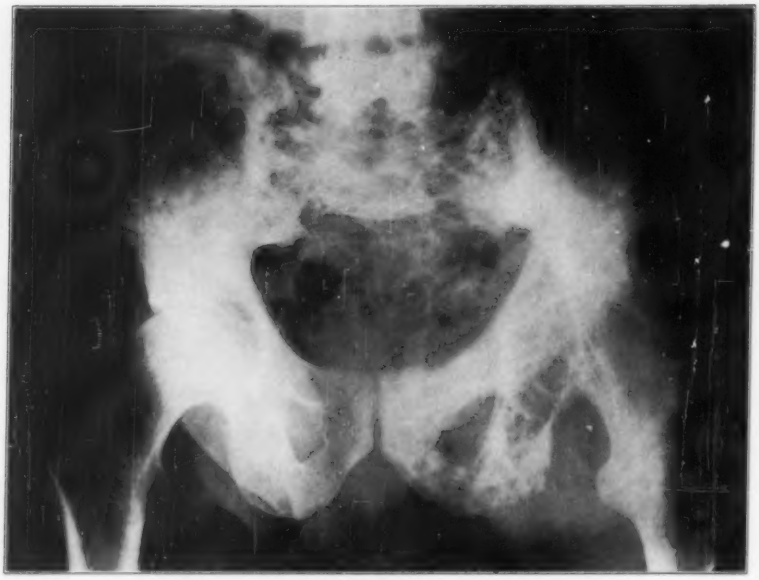

FIG. 2

Case 5. Paget's disease of the pelvis with sarcoma of the left ischium.

Fracture

In two of these sixteen patients sarcoma developed at the site of a previous pathological fracture through bone affected by Paget's disease (Figs. 1-A, 1-B, and 1-C). As far as could be determined, there was no sarcoma present at the time of the fracture. One of these fractures had healed and the other had not healed at the time when symptoms of sarcoma developed, and the time intervals between fractures and symptoms of sarcoma were six and seven months, respectively. These symptoms were not unlike those of the other patients, in whom severe pain and swelling gradually developed, but they occurred at the fracture site. The significance of these fractures will be discussed later.

Alkaline Phosphatase

Of the 1,753 patients who had Paget's disease, 882 had had 1,178 determinations of alkaline phosphatase levels. Of these, 700 determinations were expressed in Bodansky units, the upper level of normal being five units per 100 cubic centimeters of serum. One hundred and eighty of these 700 determinations were normal, the remainder being elevated. The average determination in Bodansky units was 14.3 units and the highest level was 133.9 units. Another 478 determinations were expressed in King-Armstrong units, the upper limit of normal being fourteen units per 100 cubic centimeters of serum. Two hundred and fourteen of these 478 determinations were normal, the remainder being elevated. The average determination of King-Armstrong units was 36.1 and the highest level was 412.5.

Nine patients of the sixteen with sarcoma complicating Paget's disease had had alkaline phosphatase determinations. Six of these were expressed in Bodansky units and three in King-Armstrong units. Four patients had normal and five had elevated determinations. The elevated determinations were 10.1, 55.3, and 98.0 Bodansky units and 21.7 and 71.1 King-Armstrong units.

Roentgenograms

In this series, seven patients had sarcoma of the ilium, one of the ischium, three of the

TABLE II

DATA ON SIXTEEN PATIENTS WHO HAD BOTH SARCOMA AND PAGET'S DISEASE

Case No.	Age and Sex	Duration of Pain (*Months*)	Duration of Swelling	Alkaline Phosphatase	Location of Sarcoma	Microscopic Diagnosis Osteogenic Sarcoma	Paget's Disease	Treatment	Survival Time (*Months*)
1*	62 M	3	3 mos.		Shaft right femur			Irradiation	2
2†	52 F	4	4 mos.		Distal left tibia	Grade 4 osteoblastic		Above-the-knee amputation	7
3†	57 F	5	Mass noted on examination		Right ilium	Grade 4 fibroblastic	+	Irradiation	5
4‡	44 M	3	2 mos		Greater trochanter right femur	Grade 3 fibroblastic		Irradiation	4
5	60 M	7	3 mos.		Left ischium			Irradiation	6
6	56 M	4	2 wks.		Distal left femur			Irradiation	4
7	68 M	5	Mass noted on examination	10.1 Bodansky units	Distal right humerus	Grade 3 fibroblastic	+	Shoulder disarticulation	4
8	58 M	7	7 mos.		Right ilium			Irradiation	3
9	32 M	4	Mass noted on examination	71.1 King-Armstrong units	Left ilium	Grade 3 osteoblastic	+	Irradiation	7
10	68 F	1	Mass noted on examination	98.0 Bodansky units	Left ilium			Irradiation	4
11	72 M	2	Mass noted on examination	8.6 King-Armstrong units	Right ilium			Irradiation	2
12	65 M	8	1 mo.	21.7 King-Armstrong units	Right ilium	Grade 3 osteoblastic	+	Irradiation	8
13	53 F		6 mos.	55.3 Bodansky units	Distal right humerus	Grade 4 osteoblastic	+	Irradiation; amputation	8
14	57 M	5	4 mos.	4.4 Bodansky units	Distal right femur	Grade 4 fibroblastic	+	Hip disarticulation	10
15	60 F	3	Mass noted on examination	4.8 Bodansky units	Left ilium	Grade 2 osteoblastic		Irradiation	26
16	70 M	7	7 mos.	4.7 Bodansky units	Distal left humerus	Grade 4 fibroblastic	+	Amputation	14

* Previously reported by Carman and Carrick.
† Previously reported by Dickson, Camp, and Ghormley.
‡ Previously reported by Meyerding[21].

distal portion of the humerus, four of the femur, and one of the distal portion of the tibia. Of the lesions in the femur, two involved the medial condyle, one the greater trochanter, and one the shaft of the femur at the junction of the upper and middle thirds.

Roentgenographic interpretation was often difficult, especially in lesions involving the ilium. Although a palpable tumor was present in every patient, the roentgenograms made at the time of the first examination were often inconclusive. In eight cases, such as those shown in Figures 2 and 3, the roentgenograms were interpreted as showing Paget's disease with sarcoma. Two cases, both of the ilium, were interpreted as showing Paget's

FIG. 3

Fig. 3: Case 13. Paget's disease of right humerus with large, destructive osteogenic sarcoma in medial epicondylar region which extended proximal to the surgical neck.

Fig. 4: Case 7. Right humerus involved by Paget's disease, sectioned longitudinally. Sarcoma had involved the distal portion of the humerus, and a second osteogenic sarcoma is present in the middle third of the shaft.

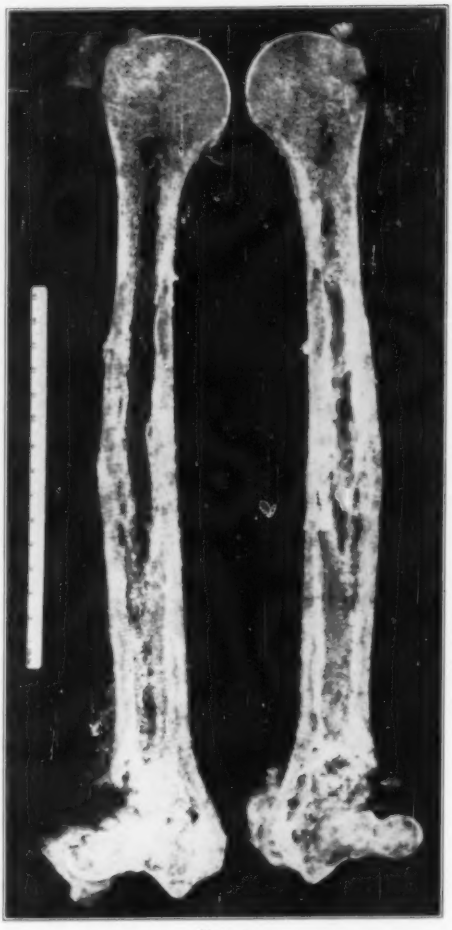

FIG. 4

disease only. Three cases, two of the ilium and one of the medial condyle of the femur, were interpreted as Paget's disease with a cystic area or with a large area of fibrous replacement of bone. Three cases, one each in the ilium, distal portion of the humerus, and greater trochanter of the femur, were interpreted as Paget's disease but with the caution that a malignant lesion could not be definitely excluded. Three of the sarcomata were osteoblastic as seen roentgenographically and the other thirteen were osteolytic or predominantly so.

Of prognostic interest is the fact that roentgenograms of the chest revealed that five of these sixteen patients had evidence of pulmonary metastasis at the time when they were first seen. One of these also had metastatic lesions in his skull, and a sixth had roentgenographic evidence of metastasis in the femoral neck and ischial tuberosity.

Gross Appearance

Four amputated specimens were available for study, and the remaining gross specimens consisted of variable amounts of fragments of tumor and bone removed for biopsy. Of the complete specimens, there were three upper extremities and one lower extremity. Sarcoma involved the humerus in each upper extremity. In one of these a palliative amputation had been done through bone grossly involved by tumor. The largest part of

FIG. 5

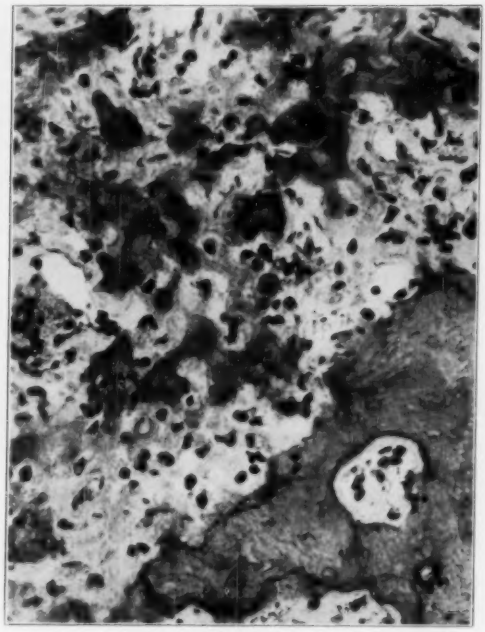

FIG. 6

Fig. 5: Case 14. Distal portion of right femur with Paget's disease, sectioned longitudinally. Osteogenic sarcoma involves the medial condyle.

Fig. 6: Case 12. Paget's disease and osteogenic sarcoma in the same section (hematoxylin and eosin, × 200).

this tumor was at the lower end of the humerus, which was expanded and showed destruction of the cortex medially. The tumor extended up the medullary cavity to the line of amputation at the surgical neck of the humerus. The non-malignant portion of the cortex of this humerus was thickened, rough, and irregularly trabeculated.

In another case, the lower half of the humerus was almost completely destroyed by tumor and the marrow cavity was invaded for five centimeters proximal to the area of cortical destruction. The remainder of the bone was also thick, rough, and irregularly trabeculated. In a third case (Fig. 4), sarcoma was found to have destroyed the distal end of the humerus and to have invaded the elbow joint, while twelve centimeters proximal to this tumor was a second smaller sarcoma. The remainder of the bone was similar to that in the two preceding cases.

In the fourth amputated extremity the sarcoma involved the medial condyle of the femur (Fig. 5). There was cortical destruction but no invasion of the knee joint. The distal nineteen centimeters of the femur were thick, rough, softened, and irregularly trabeculated, showing the typical appearance of Paget's disease of bone.

Microscopic Appearance

Distinct evidence of Paget's disease (Figs. 6, 7, and 8) was present microscopically in seven of the ten cases in which the tissue was available for study. In the remainder of the cases, the tissue did not contain non-malignant areas of bone. Areas of Paget's disease showed an unorganized pattern of bone trabeculae and the mosaic structure produced by irregular cement lines. Between the trabeculae was vascular fibrous tissue, the cellularity of which varied. There were areas of osteoblastic and osteoclastic activity.

In five of the seven cases in which Paget's disease was seen microscopically, the

FIG. 7

Case 13. Cross section of humerus. Paget's disease involves the peripheral areas, while the dark area in the medulla is osteogenic sarcoma (hematoxylin and eosin, × 2).

fibrous tissue in some or in all areas was extremely cellular (Fig. 9). The cells were predominantly plump spindle cells with numerous osteoblasts lining the bone trabeculae. Interspersed in several cases were many benign multinucleated giant cells of the osteoclast type.

Sarcoma was demonstrable in all ten of the cases in which tissue was available for study. All ten of these were osteogenic sarcoma, that is, in every case some of the malignant cells produced osteoid. Five of these were predominantly osteoblastic, and five were predominantly fibroblastic. These sarcomata tended to be highly malignant: five were Grade 4, four were Grade 3 and only one was Grade 2, according to Broders' method. These sarcomata were very cellular, with many hyperchromatic nuclei showing marked pleomorphism. Malignant giant cells and mitotic figures were common. The number of benign multinucleated giant cells within the tumor tissue was variable, but they were found in half of the cases (Fig. 10).

Treatment

Eleven patients were treated with roentgen therapy alone, and five underwent amputation of the involved extremities. One of the amputations was performed elsewhere.

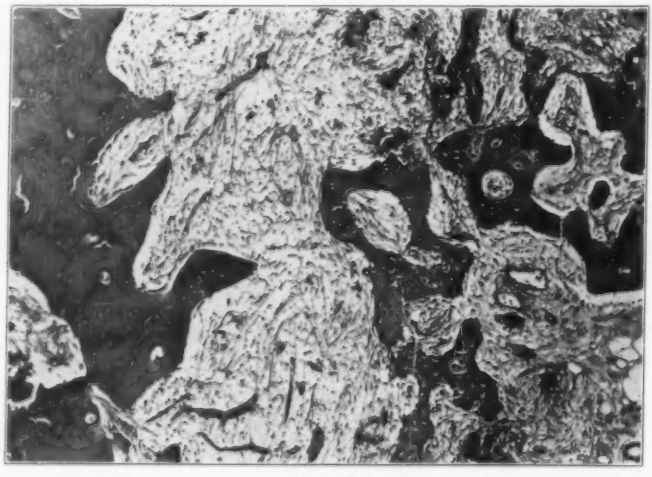

FIG. 8

Case 13. Higher magnification of a peripheral area of section shown in Fig. 7. Typical Paget's disease is shown with vascular, fibrous stroma, osteoblasts, and osteoclasts along irregular trabeculae, and mosaic cement-line pattern (hematoxylin and eosin, × 50).

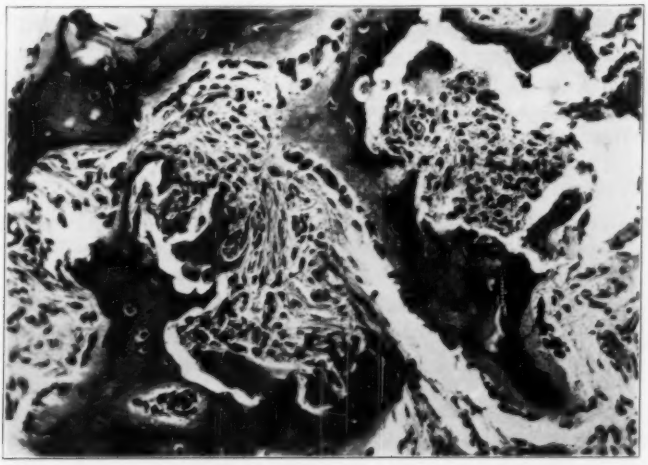

FIG. 9

Case 12. Paget's disease with very marked cellular activity. Such areas might be called presarcomatous (hematoxylin and eosin, × 200).

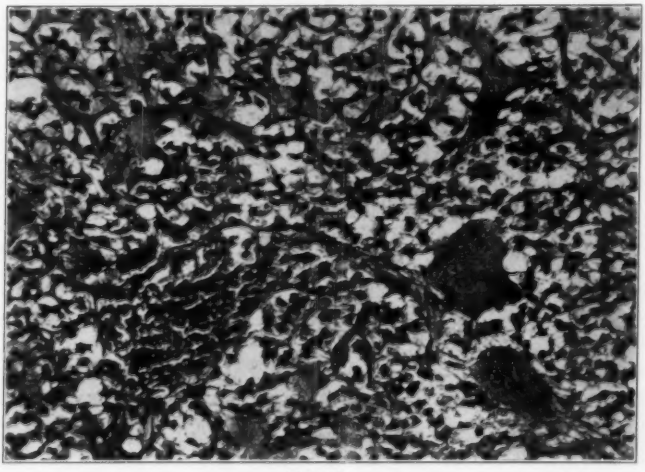

FIG. 10

Case 13. Higher magnification of a central area of the section shown in Fig. 7. Osteogenic sarcoma is shown. Two benign, multinucleated giant cells are present in this area (hematoxylin and eosin, × 300).

Another patient had been given roentgen therapy elsewhere after she had refused amputation. A palliative amputation through sarcomatous bone was performed in this patient because of impending skin ulceration by tumor, although pulmonary metastasis was already evident. Palliative amputation was performed on another patient in whom metastasis to the lungs and skull had already taken place and in a third who had roentgenographic evidence of metastasis in a femoral neck and an ischial tuberosity. Therefore, of four amputations performed at the clinic the procedure was palliative in all but one.

All patients with sarcoma involving the pelvis were given roentgen therapy. Two other patients, one with sarcoma of the greater trochanter of the femur and the other with sarcoma of the upper shaft of the femur, were given roentgen therapy since the tumors

were considered non-resectable. An eleventh patient with sarcoma of the distal portion of the femur who refused amputation was given roentgen therapy. Three of these patients given irradiation therapy had evidence of pulmonary metastasis at the time of their primary examination and in all of these eleven patients roentgen treatments were considered palliative.

Results

All sixteen patients are dead as a result of the sarcoma. Survival time ranged from two months to twenty-six months from the time of diagnosis and treatment, with an average of seven months. The average survival from the time of onset of symptoms of the sarcoma was twelve months.

COMMENT, INCLUDING ANALYSIS OF DATA ON 128 CASES FROM THE ENGLISH-LANGUAGE LITERATURE AND THE PRESENT SERIES

Critical analysis suggests that despite the high figures for the incidence of sarcoma complicating Paget's disease of bone, the true incidence is probably quite low. The present study, with an incidence of 0.9 per cent, lends support to that opinion. There are perhaps two reasons for the low incidence in the present series: (1) more and more cases of Paget's disease are found incidentally as the frequency of roentgenographic examination increases and (2) this series includes not only hospital patients, into which category all of the sarcomata fall, but ambulatory clinic patients as well.

Kolodny, reporting on material from the Registry of Bone Sarcoma of the American College of Surgeons, found that 5 per cent of all osteogenic sarcomata arose in lesions of Paget's disease. The surgical cases in this series represent 2 per cent of all osteogenic sarcomata treated surgically at the Mayo Clinic [13].

Age

Of the 128 patients reviewed from the English-language literature and from the present series the age was given in 104 cases. The average age was 58.3 years. The age distribution is shown in Table I.

The average age of the 1,753 patients with Paget's disease in this series and that of the 104 patients with Paget's disease and sarcoma are practically the same. That Paget's disease is so often asymptomatic is borne out by the high incidence of patients with sarcoma who were unaware that they had Paget's disease. Although we probably can determine fairly accurately when the sarcoma began, we can rarely determine when the Paget's disease began and so must leave unanswered the question of how long a latent interval one can anticipate.

Coley and Sharp noted that 28 per cent of their patients with osteogenic sarcoma more than fifty years of age had Paget's disease. In our series the incidence was 18 per cent [13].

Sex

Sex was given in 125 of the 128 cases of sarcoma with Paget's disease reviewed. There were eighty-four men and forty-one women, giving a ratio of about two to one, which is approximately the same as that found in the series of Paget's disease without sarcoma.

Signs and Symptoms

Signs and symptoms of sarcoma complicating Paget's disease are not unusual but are very important. Pain, both local and radiating, and swelling are present in practically every patient and are usually the first symptoms. The importance of these symptoms is realized when it is noted that twelve of the sixteen patients in the present series had sought prior medical treatment but the correct diagnosis had not been made.

Fractures

We found no mention in the English-language literature as to the significance of fractures in the etiology of sarcoma complicating Paget's disease. And yet, of the seventy-eight patients who had long-bone involvement by sarcoma, fourteen (18 per cent) had had recent fractures in the same area where sarcoma later developed[7, 9, 15, 18, 21, 41, 42, 49, 50, 54, 55]. These were all pathological fractures in that they all involved areas of Paget's disease, but there was no indication that sarcoma had been present before the fracture. There were several other cases in which fracture occurred after the sarcoma had developed, but these are not included among the 18 per cent. Except for Platt's two cases, in which the delay between fracture and first symptoms of sarcoma was twenty-three months and fourteen months, respectively, the delay was between six weeks and seven months, with an average of 3.2 months. In some cases the fracture had healed before the sarcoma developed, and in others it had not healed. Pain and swelling, developing at a fracture site several weeks or months after fracture, should be regarded with extreme suspicion.

Both Paget's disease and repair of fracture have fibroblastic and osteoblastic activity, and the sarcomata developing in Paget's disease show similar cellular activity. It seems possible, then, that when fracture is superimposed on active Paget's disease the healing reaction may progress to true neoplasia. Osteogenic sarcomata are rare after fractures, but Kolodny reported a case in which an osteogenic sarcoma of the mid-shaft of the humerus developed in a fourteen-year-old boy at the site of a well healed fracture which had preceded the sarcoma by seven months.

Howl ikely is a given fracture of an extremity with Paget's disease to develop sarcoma? This question cannot be answered, but statistical evidence indicates that a distinct hazard exists. It would seem that surgical procedures such as osteotomy in Paget's disease may introduce a similar hazard from the healing reaction that ensues. In the case reported by Breslich, a cyst in the tibia had been curetted, and ten months later osteogenic sarcoma was identified microscopically in the same area. This lesion may have been osteogenic sarcoma from the onset, but the possibility of surgical treatment being an etiological factor cannot be ignored.

Although the data indicate that sarcomata in Paget's disease may be secondary to fracture in some cases, one cannot prove that the fractures were not through bone affected by preclinical sarcoma. In any event, if fracture through a bone with Paget's disease alerts the clinician to the possibility that a sarcoma may be present or may soon develop, it has served a useful purpose.

Roentgenograms

In the present series of sixteen cases, roentgenograms alone could not be depended on to enable one to make the diagnosis of sarcoma complicating Paget's disease. In some cases, especially with long-bone involvement, cortical destruction was prominent and the diagnosis was relatively easy. Cortical destruction, however, being such an important roentgenographic sign, sarcomata of the ilium pose a particular problem, since the cortices usually are not seen in profile. Paget's disease may, as seen roentgenographically, be osteoporotic or osteosclerotic, or mixed lesions and cystlike areas may be present. These protean manifestations may mask evidence of sarcoma, especially in the early stages.

However, in a patient with recent onset of pain, swelling or both, roentgenograms are valuable in locating suspicious areas for removal of biopsy specimens. In fact, when the roentgenogram is studied in relation to the patient's history and examination, the diagnosis can invariably be strongly suspected.

Location

In twenty-seven (21 per cent) of 128 cases of sarcoma in Paget's disease, the lesions were considered to be multicentric by the authors reporting the cases. It is difficult to

TABLE III

SKELETAL DISTRIBUTION OF SARCOMATA IN 128 CASES IN WHICH THEY COEXISTED WITH PAGET'S DISEASE

Location	Monostotic Cases	Polyostotic Cases	Unknown	Total	Per cent of 128 Cases
Femur	21	9	2	32	25
Humerus	19	9	2	30	23
Pelvis	21	5	2	28	22
Skull	13	10	2	25	20
Tibia	11	5	1	17	13
Scapula	2	3	1	6	5
Vertebra	2	3		5	4
Radius	2	2		4	3
Mandible	2	1		3	2
Rib		3		3	2
Sacrum	1	1		2	2
Ulna		2		2	2
Sternum		2		2	2
Clavicle		1		1	1
Maxilla		1		1	1
Calcaneus	1			1	1

evaluate a case with multiple involvement of bone and determine whether a given lesion is metastatic or another primary. In many of the twenty-seven cases, the lesions were almost certainly multicentric, whereas in other cases the lesions were probably metastatic. Copeland studied skeletal metastases from carcinoma and from sarcoma and found that the spinal column, pelvis, femur, skull, and ribs, in that order, showed the highest incidence of involvement. It is interesting to note that of the twenty-seven multicentric cases, sixteen involved one or more of these bones. Ribs were uninvolved except in multicentric cases, and a high percentage of the vertebral and skull sarcomata were found in multicentric cases. On the other hand, eleven of the twenty-seven multicentric cases showed no involvement of these areas. These latter include such cases as one reported by Coley and Sharp, in which the leg was amputated for sarcoma of the tibia and two years later sarcomata of the upper portion of the humerus and ulna occurred.

The skeletal distribution of sarcomata in 128 cases in which they coexisted with Paget's disease is shown in Table III. The bones more commonly involved by sarcomata with Paget's disease are the femur, humerus, pelvis, skull, and tibia, in that order of frequency. This corresponds reasonably well with the skeletal distribution of Paget's disease as reported by Dickson, Camp, and Ghormley, except for the high incidence of Paget's disease of the vertebrae and the low incidence of Paget's disease of the humerus.

Coventry and Dahlin recently reviewed more than 400 cases of osteogenic sarcoma seen at the Mayo Clinic. Except for the relatively large number of lesions of the lower portion of the femur, upper portion of the tibia, and jaws, and the paucity of lesions of the skull, the distribution is similar to that of the sarcomata in Paget's disease.

Microscopic Pathology

All ten of the sarcomata examined microscopically in this series were osteogenic sarcomata. In Sherman and Soong's series, all nineteen patients had osteogenic sarcoma. Reviewing the microscopic descriptions of cases in the English-language literature, it is apparent that most, if not all, of the sarcomata arising in Paget's disease are osteogenic sarcomata.

Malignant giant-cell tumor or malignant osteoclastoma has been reported occurring in Paget's disease [22,36,47]. The frequent occurrence of benign giant cells in osteogenic sarcomata [9] is probably responsible for this type of interpretation.

The gradual transition from Paget's disease to sarcoma as noted in microscopic sections from multiple areas of an involved bone was first described by Gruner, Scrimger, and Foster. According to Jaffe, von Albertini described areas of cellular sarcoma-like marrow with large spindle cells which did not destroy or invade surrounding structures and interpreted these as presarcomatous changes in Paget's disease. Such active, benign zones were found in five of the seven cases in this series in which areas of Paget's disease were seen microscopically alongside the sarcoma.

Treatment and Prognosis

The treatment of sarcoma in Paget's disease has been amputation, local excision, roentgen therapy, radium therapy, and supportive measures. The results have been discouraging. Of 128 cases in the English-language literature, the only five-year survival was of a patient given roentgen therapy and reported by Sherman and Soong. Only five two-year survivals are recorded [10,21,32,42].

Several factors militate against a good prognosis. These include the high grade of malignancy of the sarcoma, the location of so many of the lesions in areas difficult to treat, as for example in the skull and pelvis, multicentricity of the sarcomata, and delay between the onset of symptoms and the treatment. The successful use of hindquarter amputation may improve the results with early lesions of the pelvis. If the salvage rate is to rise from practically zero, however, the diagnosis must be made sooner and treatment be instituted promptly. One should consider that any patient with Paget's disease of bone with recent onset of pain (or increase of pain) or swelling, or both, has sarcoma. Then a generous biopsy specimen should be removed from the swelling or suspicious area seen roentgenographically.

It does not seem practical to follow every patient with Paget's disease with annual roentgenograms. Not only is this probably too infrequent but roentgenograms alone cannot be depended on as the basis for diagnosis of sarcoma in Paget's disease. The diagnosis is principally a clinical one. The patient who has Paget's disease should be informed of the symptoms of this rare complication and advised to return immediately should pain (or increase of pain) or swelling develop.

The treatments of sarcoma in Paget's disease, although not curative, have nevertheless served an important purpose. Both amputation and roentgen therapy have been of palliative value in relieving pain, although roentgen therapy is not always successful in this regard and often its relief of pain is temporary. Nor are all the lesions amenable to surgical therapy, and relief by this means lasts only until the symptoms of metastasis or of another sarcoma intervene.

SUMMARY AND CONCLUSIONS

Sixteen cases of osteogenic sarcoma have been found among 1,753 examples of Paget's disease of bone seen at the Mayo Clinic. A clinical and pathological study of these cases has been presented. The English-language literature has been reviewed, and a total of 128 cases have been discussed and evaluated as a group.

The incidence of sarcoma among our 1,753 patients with Paget's disease was 0.9 per cent. The average age of patients in whom the two conditions coexisted was fifty-eight years with a range from thirty-two to seventy-two years.

The sex ratio of 1,753 patients with Paget's disease was two to one, males to females, and this ratio was the same in the 128 collected cases of sarcoma in Paget's disease.

Pain, swelling or both were present in every case of sarcoma in Paget's disease, and these were the most important clinical features in the diagnosis. Many patients were

unaware of the presence of Paget's disease until sarcoma developed. Of the sarcomata in Paget's disease of the long bones, 18 per cent developed at the site of recent fractures, which may or may not have preceded the onset of sarcoma.

All ten of the sarcomata examined microscopically in this series were osteogenic sarcomata. In five of the seven cases in which Paget's disease was also noted microscopically, very cellular areas were seen, areas which might be termed *presarcomatous.*

The prognosis of sarcoma in Paget's disease is poor, only one five-year survival being found among 128 cases reported in the literature. Treatment has consisted in amputation or roentgen therapy. Delay in diagnosis and treatment is considered to be one of the factors in the poor prognosis, and suggestions for improvement are made.

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Sporotrichosis

A Report of Twenty-three Cases in the Upper Extremity *

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Sporotrichosis is an infectious granulomatous disease of fungous origin occurring most commonly in an upper extremity. Although the disease usually involves skin and subcutaneous tissue, it has been reported, rarely, in bones, joints, muscles, synovial membranes, the central nervous system, mucous membranes, and viscera [16]. If sporotrichosis is diagnosed, it can usually be cured; in fact, no other deep fungous infection responds more readily to treatment. If unrecognized, the disease will not spontaneously regress, and a chronic disability will result.

HISTORY AND GEOGRAPHIC DISTRIBUTION

Sporotrichosis was first described in the United States, in 1898, by Schenck. He described a patient with the primary lesion in a finger and secondary lesions in the forearm. He cultured the organism twice, and Smith, collaborating with Schenck, placed the organism in the genus *Sporotrichum*. Hektoen and Perkins, in 1900, reported a second case, and named the organism *Sporotrichum schenckii*. The first non-American case to be reported was by de Beurmann and Ramond of France, in 1903.

The disease has been reported from every continent. In the United States it appears to be more prevalent in the North Central portion than in other portions and is considered to be endemic in the Mississippi Valley. Foerster [9], in an analysis of 148 reported cases, found 111 occurring in the Missouri-Mississippi River Basin. By 1952 [31], cases had been reported from twenty-nine states. Dobes, in 1952, reported six cases of his own in Georgia and, through a poll of ten physicians regarding their cases from 1942 to 1952, found forty additional unreported cases. These facts suggest that the disease is more common than one would imagine and that this specific infection should receive more attention.

SOURCE OF INFECTION

There is evidence that the organism thrives where relative humidity is high. This was especially true in the South African epidemics [28]. The disease is noticeably absent in our own Pacific Northwest, however. The organism is hardy, but it is thought to be of low virulence, and sporotrichosis possibly develops when resistance of the host is lowered. The source of infection has broad possibilities, since the organism exists as a saprophyte in nature. It has been isolated from plants, flowers, and sawed timbers. The ability of the organism to penetrate the intact mucosa may explain the mode of infection in some of the systemic cases. However, in the vast majority of cases infection is through a break in the skin. At least two investigators have been infected while working with cultures of the organism, and it has been shown that the disease may follow handling of contaminated dressings from infected patients [8]. It has not been reported as being transferred directly from man to man. Less common sources of infection have been reportedly horses, bites of rats, gophers, white mice, and parrots. The epidemic of 2,825 cases in

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South African gold mines came from supporting timbers of the mine. This was established by culture [28].

CLINICAL FEATURES

In our own series of twenty-three patients with involvement of an upper extremity, the age range varied from sixteen to seventy-four years with an average of forty-two years. The youngest patient to be reported in the literature was sixteen months of age; the oldest was seventy-one [3]. In our series the distribution was twelve men and eleven women. All races seem to be equally susceptible.

Sporotrichosis, as pointed out by Foerster [9], is to an extent an occupational disease, frequently occurring among people who work with soil and vegetables. In this group farmers, laborers, and florists are commonly affected. With this in mind, we believe that more attention should be given to sporotrichosis as a compensable disease. Some [19, 30] have reported compensable cases in the state of New York. Singer and Muncie reported infection in workers on flower-bulb farms where salt-marsh hay was used as mulch. Gastineau and associates have reported infections occurring in florists who used various fertilizers. Foerster [9] reported fourteen cases resulting from injury and infection by the Japanese barberry bush. In our series seven patients were housewives, in most of whom the infection occurred after an injury while working with thorned flowers, five were farmers, five were florists, one was a laborer, one was a carpenter, one was a clerk in a grocery store, one was a stenographer, one was a cashier in a clothing store, and one was a manager of an automobile agency.

Only nine (43 per cent) of our twenty-one patients who had primary lesions of the skin (two patients had systemic infections with no primary lesion ever being found) recalled a specific injury at the site of the subsequent primary cutaneous lesion. Three pricked a finger on a rose thorn, one cut a finger with a knife, one scratched an arm on a raspberry bush, one on a cornstalk, and one on a Japanese thorned shrub, while one abraded a hand on a leather strap, and one was injured by a sliver of wood in a wrist.

CLASSIFICATION AND PATHOGENESIS

Sporotrichosis manifests itself in various forms. The classic work of de Beurmann and Gougerot described the disease as composed of one or more of six different clinical types[3]: lymphatic, disseminated, epidermic, mucosal, skeletal, and visceral. Smith and Garrett have added a seventh type, sporotrichotic dermatitis.

World-wide distribution of cases readily falls into the foregoing classifications. However, our own series, and other American cases, appear to fit appropriately into the classification of Moore, who divided sporotrichosis into three groups: localized, gummatous disseminated, and extracutaneous or systemic. Foerster [8] found that in sixty-two of 109 published cases the lesions occurred in an upper extremity, with a majority occurring on the right hand.

In twenty-one of our twenty-three patients the disease began as the localized lymphatic type, and in one of these twenty-one cases it progressed to the systemic type. Thirteen (65 per cent) of the primary lesions occurred in the right upper extremity. Eleven of these occurred on the dorsal or volar aspect of the hand. Three lesions occurred on the volar aspect of the left forearm. The localized lymphatic form may be cutaneous or subcutaneous. The cutaneous form is characterized by ulcers, nodules, gummata, and abscesses, with the primary lesions occurring at the site of injury. The wound of entry may be a previous one later contaminated by the organism, or the initial injury may introduce the organism by a contaminated thorn, for example. From twenty days to three months may elapse following inoculation before appearance of the primary lesion.

The primary lesion may begin as a small abscess at the site of trauma. The abscess

FIG. 1

Fig. 1: Primary lesion of sporotrichosis on the dorsal surface of the index finger. The pustule has ruptured and ulcerated.

FIG. 2

FIG. 3

Fig. 2: Primary lesion of sporotrichosis located on radial aspect, distal phalanx of right index finger. Multiple secondary nodules and ulcers appear on the forearm and arm. This clinical picture illustrates the localized lymphatic type of sporotrichosis.

Fig. 3: Primary lesion of sporotrichosis on dorsum of hand with multiple ulcerative and nodular secondary lesions on the dorsum and forearm. Typical case of localized lymphatic type of sporotrichosis.

enlarges to form a nodule, which is at first semisolid, spherical, freely movable, and nontender. It then becomes attached to the skin, which is first pink, gradually becoming violaceous. The nodule forms a fluctuant center and ruptures spontaneously, forming a granulomatous ulcer, which bleeds easily and tends to crust (Fig. 1). The ulcer may heal spontaneously, or it may remain open and is then known as the primary chancre; this may persist for months. Only three cases have been reported in the American literature in which the disease has remained in this localized form [21]. Commonly, within a few days to a week after the appearance of the primary lesion, the fungus spreads through the lymph channels to produce an ascending chain of secondary subcutaneous nodules. The lymph channels may appear as firm, cordlike, painless structures. The nodules may number from three to forty or more. These nodules are freely movable and painless. Later they become attached to the skin. They may also soften and ulcerate, discharging a small amount of thin, watery secretion (Figs. 2 and 3). Secondary lesions vary in appearance in the same case, based on the evolution of the disease process, nodules and ulcers appearing simultaneously. The secondary lesions, unlike the primary lesion, may persist for months or years if the disease is not treated. As a general rule, in the localized form, the general health is not affected.

The second group, or gummatous disseminated type, is rarely seen in this country, but commonly encountered in France. None of our patients were in this group.

The third group is the extracutaneous or systemic group. Three of our cases were of this type. Fortunately, the systemic group is uncommon, for these cases are perplexing diagnostically as well as therapeutically. We shall discuss the systemic group in greater detail later, with brief summaries of our three cases. However, it is appropriate to mention that the granulomatous lesions may appear in muscles, bones, joints, and synovial mem-

branes. In bone the lesion may appear as periostitis or osteomyelitis. Spontaneous fractures have been reported, and Gougerot stated that bone is affected in approximately 10 per cent of systemic cases.

MYCOLOGY

At one time ten species of *Sporotrichum* were listed as causative agents of sporotrichosis, but today it is the consensus among mycologists that *Sporotrichum schenckii* is the etiologic agent and that the other previously described species are actually variants of this species. *Sporotrichum schenckii* is rarely recognized in secretions, potassium iodide preparations, or stained smears from lesions, and is similarly rarely observed in the

FIG. 4

Culture of *Sporotrichum schenckii*, illustrating the well developed filamentous form. The growth is black and wrinkled and now appears as a giant colony.

tissue of biopsy specimens. An asteroid body rarely appears in biopsy specimens in this country but is rather commonly seen in cases from South America and South Africa. It represents a central cell of *Sporotrichum* with peripheral, radiating extensions, analogous to ray forms in actinomycosis. If, however, the organism should be seen in tissues or secretions, it appears as a short, blunt, gram-positive rod with a capsule-like, colorless periphery. The most reliable method of identifying the causative organism, therefore, is by culture. In choosing material for culture, it is preferable to aspirate an unopened nodule with a sterile needle and syringe or to utilize secretion from an open lesion by swabbing. Excisional biopsy of a small nodule may be utilized, since the examining mycologist can select an area for culture. This is probably the procedure of choice, for the biopsy material can be ground up and cultured with the best chance of isolating the

organism. The organism usually appears on the second to the fifth day as a small, pinpoint colony, at first white or cream-colored and smooth, indicating absence of aerial mycelium. A few days later, growth increases, and the surface of the colony becomes moist and wrinkled. The color gradually changes from white to gray, and finally the appearance of black, wrinkled, and leathery growth is apparent (Fig. 4). It must be borne in mind that color variations have little significance with *Sporotrichum schenckii*, since the same strain may go through these color changes. Reid has shown that addition of thiamine to the medium produces a more abundant growth of the organism. Also, the addition of fifty units of penicillin and streptomycin inhibits the growth of secondary bacterial contaminants.

Microscopically, on suspension of culture the appearance is of a tangled filamentous mycelium, the hyphae being approximately two to three micra in width and septate. The hyphae also give rise to short lateral conidiophores or branches, on the tips of which are clusters of oval or pyriform conidia two to four micra in length (Fig. 5). Conidia, although ordinarily seen projecting from lateral branches, may be sessile.

The yeast phase may be obtained on fresh meat infusion blood agar at 37 degrees

FIG. 5

Culture mount of *Sporotrichum schenckii*, showing the delicate, septate hyphae with lateral branches, which terminate in clusters of typical pyriform conidia (× 450).

centigrade. Growth generally appears in two to three days. Microscopically, these colonies are composed of spherical, ovoid, or pyriform budding cells, which measure up to six micra in length. When stained, they appear gram-positive. These are the cells so rarely seen in biopsy specimens. The cells may be freely dispersed in necrotic material, or phagocytized by mononuclear leukocytes or macrophages. We were unable to identify the cells in any of our biopsy specimens.

Mycologically, the diagnosis may be further confirmed through intraperitoneal inoculation of secretions aspirated from nodules into white mice or rats. In nine to twenty

days the animal will probably die with peritonitis, and at necropsy extensive involvement of lungs, liver, and other organs will be seen. The organism can be readily demonstrated by direct smear or in tissue sections as numerous gram-positive ovoid to pyriform cells[3,28].

HISTOPATHOLOGY

The histopathological appearance of sporotrichosis may be confused with that of tuberculosis, syphilis, and other granulomatous diseases. The histopathological manifestation in sporotrichosis varies considerably from case to case. Frequently the reaction is one of necrosis, with suppuration mixed with subacute and chronic inflammation. The histiocytic reaction in such cases may be difficult to recognize except for the presence of an occasional multinucleated giant cell. In other cases the reaction may be predominantly granulomatous, with focal areas of necrosis surrounded by epithelioid cells forming clear-cut lesions (Figs. 6, 7-A, and 7-B) suggestive of tuberculosis. In still other lesions there may be various degrees of mixtures of these two reactions. In any case it is well to remember that the organisms usually are not found in the histological sections of human lesions, even if stained specifically for fungi by means of Gridley, silver chromate, or periodic-acid Schiff techniques. Accurate diagnosis will therefore rest *entirely* on the isolation of the organism.

It is well to remember that *Sporotrichum schenckii* is dimorphic and will appear in cultures either as a budding yeastlike organism forming smooth, moist colonies somewhat resembling those of micrococci or as grayish-white filamentous colonies, which turn brown or black and become leathery in texture, depending entirely on the conditions of growth. The former is an important feature, since ulcerating lesions may contain micrococci and require that special attention be given to all the colonies present.

DIAGNOSIS

The average time from onset of the disease to diagnosis in our own cases was three months, the longest period being six months. This time interval can be shortened by more acute awareness of the clinical features in this disease.

Sporotrichosis should be considered a chronic illness in which cutaneous or subcutaneous nodular lesions suggesting lymphatic dissemination appear without the usual inflammatory signs of bacterial infection. The disease is seen most commonly in an upper extremity. The diagnosis is established by demonstration of the causative organism, *Sporotrichum schenckii*, following the previously outlined culture technique. An adjunct to the diagnosis may be animal inoculation, although this is usually not necessary. Complement-fixation or agglutination tests are not specific, since they often give false-positive results. An intradermal skin test has been used and is primarily of value in that a negative reading rules out sporotrichosis, but false-positive readings may also occur.

Although eosinophilia has been suggested as being present in some cases [16], we were not able to confirm this finding in any of the cases being reported here. An elevated sedimentation rate was present in our three systemic cases, with leukocytosis in one of these. Leukocytosis was present in one of the localized lymphatic cases in which secondary bacterial infection was superimposed.

Sporotrichosis must be differentiated from tuberculosis, syphilis, pyogenic infections, tularaemia, coccidioidomycosis, North and South American blastomycosis, histoplasmosis, squamous-cell epithelioma [15], and granulomata caused by drugs.

TREATMENT AND PROGNOSIS

Potassium iodide remains the drug of choice for treating the localized lymphatic form of sporotrichosis. It is also of value in all other forms except central nervous-system involvement. In the systemic type, 2-hydroxystilbamidine may be helpful.

Although the mode of action of iodine is still speculative, the majority of investigators

are of the opinion that iodine has little direct action on the organism, but rather modifies the response of the host. Davis and Skinner and associates have shown that spores of *Sporotrichum schenckii* continue to multiply *in vitro* and in the presence of high concentration of iodide ions. The latter authors found survival of the organism in media containing 10 per cent concentration of potassium iodide.

Shintani and associates, using I^{131} as a tracer in diseased animal tissue infected with sporotrichosis, found that there was no selective localization of the tracer element in any of the cellular zones of the lesions observed. This supports the concept of extracellular distribution of iodine and argues against a specific effect of therapeutic iodine either on the spores of the infectious agent or on the various types of cells involved in the local tissue defense. Though the specific action of potassium iodide is not fully explained, its

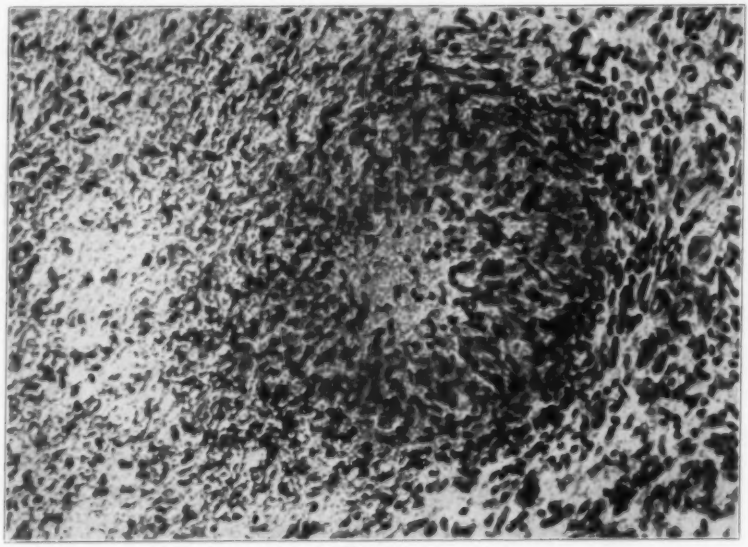

FIG. 6

Tubercle formation in a case of sporotrichosis of the ankle. Cultures for Brucella, tubercle bacilli and commont pyogens were negative. Guinea pigs inoculated with a portion of the emulsion were negative for tuberculosis. Numerous colonies of *Sporotrichum schenckii* were obtained on each medium (hematoxylin and eosin, × 230).

therapeutic effect in sporotrichosis is definite. We found in our cases that an aqueous saturated solution of potassium iodide should be administered in doses of ten grains three times a day, and increased at the rate of five grains three times a day to forty or fifty grains three times daily. It should be diluted in milk or water. It is extremely important to continue treatment for four to six weeks after apparently complete recovery in order to avoid recurrences.

Iodide therapy may be complicated by drug reactions varying from mild to severe, and deaths have been reported from its use in other diseases. There is no record of a death in this country resulting from its use in the treatment of sporotrichosis. The reaction to iodide therapy may vary considerably. Skin eruptions are commonly encountered and may vary from acneform lesions to purpuric, furuncular lesions and types of erythema multiforme. That malignant and fatal types of iododerma may follow the administration of very small amounts of iodides is well known. Although the severe reactions are rare, one must constantly keep in mind their possibility. Milder reactions in the skin, such as pruritus, often occur and may be accompanied by mild gastro-intestinal reaction, coryza, swelling and tenderness of the salivary glands, and lacrimation. Five patients

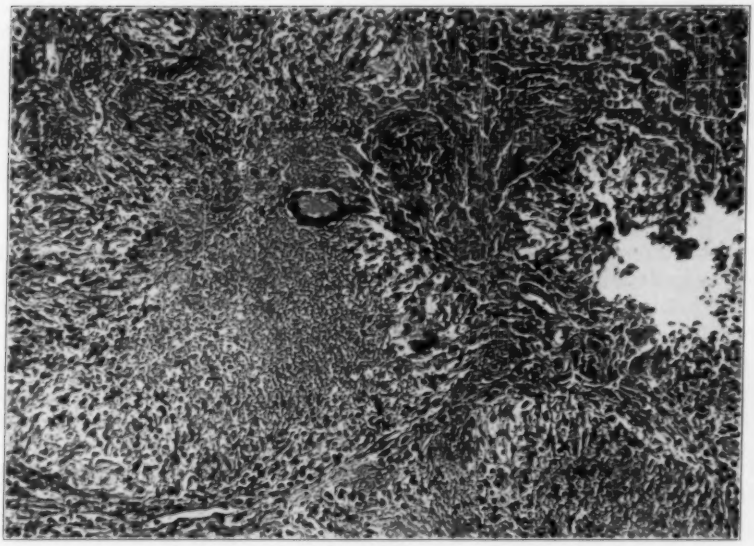

FIG. 7-A

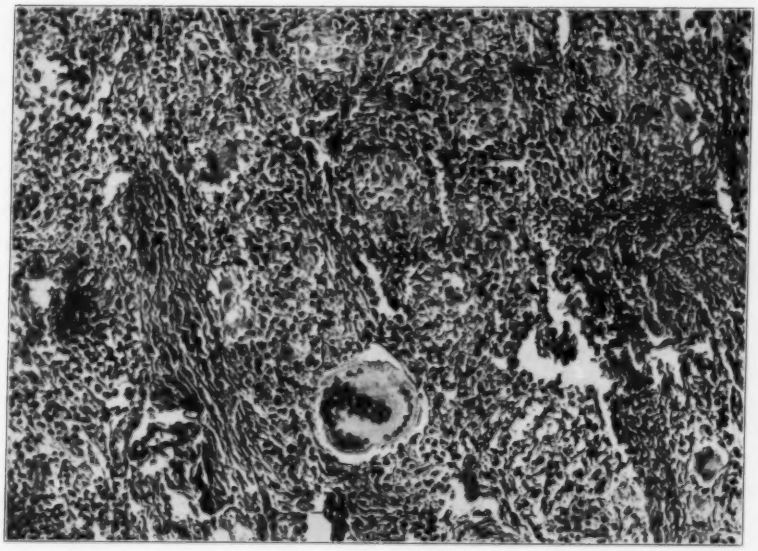

FIG. 7-B

Figs. 7-A and 7-B: Variation in the granulomatous reaction in subcutaneous solitary nodules.

Fig. 7-A: Tubercle formation as in Fig. 6 (hematoxylin and eosin, × 163).

Fig. 7-B: Diffuse distribution of histiocytes with multinucleated giant cells without necrosis. Thorough microbiologic studies yielded only *Sporotrichum schenckii* (hematoxylin and eosin, × 163).

had drug reactions in our series, two of these being only a transient diarrhoea. Administration of the drug was discontinued temporarily in these except the two patients with diarrhoea, but resumed with delayed but eventual cure of the disease. Waugh has proposed use of cortisone in severe allergic reactions to iodides, and even desensitization to iodine

has been suggested in some cases in which reaction has occurred. This was not found to be necessary in any of our cases. The response of patients to therapy may vary. If potassium iodide is not tolerated, sodium iodide may be substituted, and given intravenously in doses of one gram daily.

The report of Elson in 1945, showing that propamidine exhibits antifungal activity *in vitro*, opened up an entirely new group of chemotherapeutic agents in the treatment of deep mycotic infections. Stilbamidine has been used extensively and is clinically effective in the treatment of North American blastomycosis and actinomycosis. In 1954, Harrell and associates first reported use of stilbamidine in a case of localized lymphatic sporotrichosis. Regression of all lesions had occurred at the end of the second week of treatment, and complete healing occurred after one month. The authors stressed the possible serious toxic effects of the drug and suggested a proper dose to avoid these effects. The two commonest toxic manifestations of stilbamidine are the acute nitritoid crises and the chronic trigeminal neuropathy. The immediate reactions after intravenous injection of stilbamidine may be alarming. They consist of tachycardia, vertigo, nausea, vomiting, and headache. At least two deaths have been reported from its use, and in both of these liver atrophy was present [2]. The development of trigeminal neuropathy, which consists of sensory disturbance and dissociated anaesthesia, occurs in one to twelve months after use of the drug. It has been reported that among fifty-one cases of various diseases treated with stilbamidine, trigeminal neuropathy developed in 53 per cent [4].

With the development of a closely related compound, 2-hydroxystilbamidine, a drug of equal therapeutic value but with fewer toxic manifestations became available. In view of this, larger doses can be given. Snapper and associates stated that there had been no serious toxic reaction or trigeminal neuropathy in reported uses of the drug; however, as with stilbamidine, minor reactions may occur but can be altered by adjustment of dosage. Although 2-hydroxystilbamidine is more stable than stilbamidine, it must also be prepared freshly each day just prior to intravenous administration and protected from light during preparation and administration. The daily dose is 225 milligrams given intravenously. It should be given slowly over a period of forty-five to sixty minutes. The dose may be subsequently increased if necessary.

Because of fewer reactions, therapeutic equality, and the possibility of larger doses, 2-hydroxystilbamidine may replace stilbamidine in the treatment of certain forms of sporotrichosis. The case report by Geraci and associates of systemic sporotrichosis treated by 2-hydroxystilbamidine is the first reported use of this drug in sporotrichosis. The patient had systemic sporotrichosis, with involvement of the central nervous system. The patient appeared well on the way to recovery when a severe acquired allergic sensitivity developed. The drug was discontinued, and despite supportive therapy, the patient died. The fact that clinical improvement was present at the end of one month of therapy and that culture of all lesions at necropsy was negative, with evidence of healing of the lesions, suggested strongly that the drug may be of curative value in the systemic form of sporotrichosis.

Radiation therapy to individual lesions appears to hasten healing in some instances, but it is of no value alone.

The report of a patient with sporotrichosis who could not tolerate potassium iodide and was treated successfully by iontophoresis with strong solutions of iodine is interesting [22]. To our knowledge, however, this observation has not been repeated.

Thomas and associates reported a case of sporotrichosis which appeared to be improved temporarily by fever therapy, but the disease recurred and was not cured until treatment with potassium iodide was instituted. This would suggest that fever therapy is not curative.

The prognosis in the localized lymphatic type of sporotrichosis is excellent. We found that the duration of time from onset to diagnosis in this type did not influence

response to treatment. The average time for complete healing in our patients was 7.4 weeks, the shortest two weeks. The only factor which did seem to influence healing in this type was delay of complete treatment due to drug reaction. This occurred in five of our patients; after a temporary discontinuance of the drug in three of these patients, they subsequently recovered with potassium iodide therapy. We did not find evidence that a second course of the drug was less effective than the first, as has been reported [3].

The prognosis for the systemic group is more guarded. It is particularly grave in fulminating, disseminated forms with involvement of the viscera and of the central nervous system.

There is no reported survival in the American literature of a patient with involvement of the central nervous system. One of our patients who had systemic sporotrichosis was cured by potassium iodide in large doses. Another of these patients appeared to be recovering from involvement of the central nervous system when an allergic reaction caused discontinuance of 2-hydroxystilbamidine. Our third patient who had systemic involvement was given potassium iodide, but the follow-up is too short to enable one to evaluate its effect.

Twenty-two patients in this series were treated with potassium iodide; one was treated with 2-hydroxystilbamidine, as mentioned above. This patient died 107 days after treatment started. The lesions in patients treated with potassium iodide all healed, with no recurrence, although two patients were not followed.

SYSTEMIC SPOROTRICHOSIS

Unlike the patient who has the localized lymphatic form of the disease, the patient with systemic involvement presents a more serious and perplexing problem. Lesions of mucous membranes, lungs, muscles, osseous structures, joints, synovial membranes, and gastro-intestinal tract, as well as other viscera, the central nervous system, eyes, and testicles, have been reported. Pulmonary involvement is rare, and involvement of the central nervous system is extremely rare, only a few cases having been reported. Ochoa listed three types of systemic involvement:

1. Primary forms, in which the lesion may appear in the viscera without cutaneous involvement. In these forms it is generally unknown how the fungus gained its entrance; but, since the organism can penetrate the mucous membrane, it may well be that the disease is acquired through the oropharynx or the gastro-intestinal tract.

2. Concomitant forms, with granulomatous lesions scattered throughout the body. The organism in this group may gain entrance through the skin and spread hematogenously. Most cases of systemic involvement are in this group.

3. Forms secondary to cutaneous lymphatic types, in which secondary lesions may develop in adjacent bone, muscle, and other tissues by contiguous extension from the primary lesions.

REPORT OF CASES OF SYSTEMIC SPOROTRICHOSIS

CASE 1. (This case has been reported in detail by Geraci and associates. We shall present a brief summary of the outstanding features.) A sixty-year-old male laborer gave a history of a chronic indolent ulcer of his thumb one year prior to his admission to the Mayo Clinic. This healed very slowly. Approximately six months before admission, he had noted easy fatigability, and one month before admission he had noted a "boil" on the inner aspect of the right thigh. This drained spontaneously one week later. As this lesion healed, painless, non-tender, subcutaneous nodules were noted on both sides of his neck and trunk and over all four extremities. Two weeks prior to admission he had noted a severe lumbar backache, which persisted. At this time he also observed difficulty with speech and episodes of blindness. Subsequently, difficulty in performing fine movement with his right hand was noted. He experienced loss of weight and progressive weakness.

On physical examination, non-tender, slightly movable, subcutaneous nodules of various sizes up to two centimeters in diameter were noted in the anterior cervical region bilaterally, on the mid-anterior surface of the left arm, and on the extensor surface of the right forearm. Other lesions were present over the surface

of the right thigh, the abdomen, and the lower back. The liver was palpable to the level of the umbilicus, and the spleen was palpable one to two fingerbreadths below the costal margin.

Laboratory examination disclosed a leukocyte count of 11,200 per cubic millimeter of blood with a normal differential count, a sedimentation rate of twenty-four millimeters in one hour (Westergren), and slight microhematuria, micropyuria, albuminuria, and occasional casts.

During preliminary examination, the patient's dysarthria developed into a complete aphasia, and the right arm became paretic. The patient was hospitalized for further study.

Biopsy of subcutaneous nodules revealed *Sporotrichum schenckii* by culture, and administration of 2-hydroxystilbamidine was begun. Two days prior to the beginning of therapy the temperature had risen to 102.4 degrees Fahrenheit and two days after the beginning of therapy the patient became afebrile and his general condition improved. Within two weeks the subcutaneous nodules had almost disappeared, and complete healing was present at the end of one month. Gradual neurological improvement was noted. Subsequently, a severe acquired allergic reaction, anaphylactic in type, occurred, and administration of the drug was discontinued. A week after this, episodes of further neurological manifestation occurred. Ventriculograms were made. They were consistent with a diffuse intracranial process rather than a focal lesion, and neurosurgical measures did not seem advisable. Although potassium iodide was administered, the patient's condition deteriorated rapidly, and he died one month later.

At necropsy, healing granulomata were found in several areas of the left lobe and one area of the right lobe of the brain. A similar lesion was present in the right first sacral root. Extensive cultures were negative for *Sporotrichum schenckii*. Contributory causes of death were pulmonary oedema and renal failure coincidental with drug therapy.

Case 2. A white female stenographer, twenty-four years old, had noted onset of a "cold" three months prior to admission to the clinic. This was followed by pain in the right side of the chest on deep inspiration. The patient was afebrile. She consulted her physician, who made a diagnosis of pleurisy and performed thoracentesis of the right pleural cavity. The details of findings from this procedure were not available to us. The patient improved temporarily, but a week later she noted episodes of sharp pain in the right shoulder extending into the right arm. Approximately three weeks later this was accompanied by continuous periumbilical pain.

One month prior to admission a painful subcutaneous mass developed over the proximal portion of the right leg. Similar masses appeared in the right lower arm over the triceps tendon, and in the biceps muscle of the right arm.

Physical examination disclosed the masses to be approximately two centimeters in diameter, subcutaneous, firm, tender, and attached to the deep structures, but not to the skin. Thoracic examination revealed diminished breath sounds and dullness over the right lower chest. The results of abdominal examination were negative.

Laboratory studies were negative except for a sedimentation rate of sixty-three millimeters in one hour (Westergren). Roentgenographic examination showed consolidation of the lower lobe of the right lung. It also showed a lesion of the right tibia, a picture compatible with osteomyelitis.

Biopsy of the lesion in the right arm revealed the inflammatory process to be in the substance of the biceps muscle. Culture revealed *Sporotrichum schenckii*.

Administration of ten grains of potassium iodide three times a day was begun, and the dose was advanced to 140 grains three times a day. The roentgenogram of the chest was clear at the end of one month, and all lesions healed in six weeks. The patient's general health gradually improved, and she returned to her previous job approximately three months after leaving the clinic.

Although a positive culture was not obtained from the pulmonary tract it is thought that pulmonary sporotrichosis was present in this patient. The process cleared promptly with the institution of iodide therapy. The same applied to the process present in the right tibia.

Case 3. A white male grocery-store manager, fifty-one years old, noted bilateral tenderness of the calves three months prior to admission to the clinic. Two weeks later, indurated, painful masses appeared over both lateral malleoli, the left calf, and the dorsal surface of the right lower arm. Pain, stiffness, and swelling of both knees were present. He had lost approximately thirty pounds at the time of admission to the clinic. Twenty-nine days prior to admission he was hospitalized without a diagnosis being made. A course of penicillin did not alter the disease.

Physical examination revealed subcutaneous masses in the left calf, on the dorsal surface of the right lower arm, and over both lateral malleoli. These were firm and tender. Ophthalmoscopic examination revealed a toxic retinopathy.

Biopsy of the lesions on the right arm and left calf was performed. The first lesion was an inflammatory

mass attached to the triceps tendon, and the latter was a similar mass attached to the gastrocnemius muscle. *Sporotrichum schenckii* was found in both biopsy specimens and potassium iodide treatment was begun.

This patient represents a recent infection, and follow-up study is incomplete at this time.

COMMENT

This study represents the combined efforts of the sections of special bacteriology, dermatology, orthopaedics, and plastic surgery at the Mayo Clinic. This fact perhaps suggests the close cooperation so helpful in the diagnosis and treatment of sporotrichosis, as well as in carrying out a clinical investigation such as that reported here.

We should like to emphasize the need for culture of lesions of this type. While it is true that the clinical picture is usually characteristic, we could cite examples in which other diagnoses were entertained, and in which the patient was treated according to this mistaken diagnosis for a considerable time, with detriment, of course, to him. While all of our patients with cutaneous types of the disease had nodular lesions under the skin, those patients with the systemic types presented more difficulty in diagnosis. Infection by yeasts and related organisms may exhibit a clinical picture similar to that of sporotrichosis. It is important that the diagnosis be confirmed bacteriologically in these cases. As mentioned, this procedure is really not difficult, and is worth the effort of taking the specimen and culturing it. Although we have had little experience with bone and joint sporotrichosis, it is logical to think that treatment of such infections might very well be compared to the treatment of tuberculosis and other chronic infectious granulomata. Potassium iodide therapy in a systemic way, and perhaps 2-hydroxystilbamidine as well, and surgery which would include synovectomy, drainage of abscesses, débridement, and other obvious surgical methods should prove efficacious in the treating of skeletal sporotrichosis.

SUMMARY

Sporotrichosis is an infectious granulomatous disease of fungous origin. The causative organism is *Sporotrichum schenckii*, which is found in nature on plants, flowers, and trees, as well as in animals, insects, and birds. Sporotrichosis is most commonly seen in farmers, florists, and laborers. It is to an extent an occupational disease.

The localized lymphatic type of sporotrichosis is the commonest, constituting 70 per cent or more of reported cases. The disease occurs in skin and subcutaneous tissue and appears in an upper extremity in the majority of cases. The primary lesion is generally an ulcer at the site of inoculation of *Sporotrichum schenckii*. The ulcer most frequently appears on the hand, with secondary nodular and ulcerative lesions appearing subsequently in ascending fashion along the lymphatic channels. Secondary lesions may number three to forty or more.

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Comminuted Fractures and Fracture-Dislocations Involving the Articular Surface of the Humeral Head*

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This paper presents the findings of an end-result study of comminuted fractures and fracture-dislocations involving the articular surface of the humeral head and treated by the various methods in use prior to the advent of prosthetic procedures. The study should be useful as a yardstick for future judging of a long-term end-result study of prosthetic procedures.

TABLE I

DISTRIBUTION OF PATIENTS ACCORDING TO AGE

Age	No. of Patients
Less than 30 years	1
30 to 40 years	4
40 to 50 years	7
50 to 60 years	13
60 to 70 years	7
70 to 80 years	7
Over 80 years	1

TABLE II

LENGTH OF FOLLOW-UP

Time		No. of Patients
Less than 2 years		5
2 to 5 years		20
5 to 10 years		10
10 to 18 years		5
Minimum follow-up	1.25 years	
Maximum follow-up	18.0 years	
Average follow-up	5.3 years	

Our series consists of forty patients, twenty-five women and fifteen men, of whom all but one were over thirty years of age (Table I). They have been followed a minimum of 1.25 years; the average period of follow-up after injury was 5.3 years (Table II). All were treated by permanent members of the staff of the Campbell Clinic.

In 1955, Stewart and Hundley reported an end-result study of fractures of the neck and shaft of the humerus. Speed in 1950, and Knight in 1955, reported end-result studies of fractures of the humeral condyles in adults. The present report thus completes a series of end-result studies of the treatment of fractures of the humerus at the Campbell Clinic.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1957.

CLASSIFICATION

The fractures under consideration are those which, under Kocher's classification, would fall into the supratubercular group. Dehne's classification, though excellent from a diagnostic point of view, did not permit us to group the patients for a clear evaluation of the anatomical and functional results. We therefore used a classification more adapted to our needs. We first set up two large groups, differentiating between fractures alone (Group I) and fracture-dislocations (Group II). Each of these large groups was in turn subdivided in two, according to the degree of fragmentation: Subgroup A, in which a fairly large cartilage-covered fragment remained, and Subgroup B, in which fragmentation and displacement were severe.

EVALUATION OF RESULTS

Sever stated that the result obtained in an average fracture involving the head and neck of the humerus is seldom satisfactory if, by a good result, one means the restoration of the part to normal function. At first glance, this statement appears unduly pessimistic. Yet, as Sever went on to say, "If so much permanent disability can result from an arthritis or periarthritis of the shoulder joint or from a chronic subdeltoid bursitis, why should a more extensive injury to the intrinsic structure of the joint itself give better results?"

TABLE III

DEGREE OF PAIN

Degree	No. of Patients
None (= 0)	24
Mild (= 1)	7
Moderate (= 2)	7
Severe (= 3)	2

Early in our present study it became evident that if one were to consider as having a good result only those patients in whom 75 per cent or more of normal motion was restored, the number of unsatisfactory results would be very high. On the other hand, it was equally evident that some of the patients had a result which was most acceptable to them. For example, a patient may be well satisfied because his shoulder proves painless and its strength good, and because he can bring his hand to his mouth and can place his hand behind his back and behind his head with little or no difficulty. The surgeon may well be dissatisfied with the same result because of serious limitation of extremes of motion and because the roentgenographic result is disturbingly poor. Furthermore, what is a satisfactory result following a severe fracture-dislocation may be a disappointing result following a less severe fracture without dislocation. Indeed, throughout the study, we noted a remarkable lack of correlation among four factors: the anatomical result, the functional result, the patient's satisfaction with the result, and the amount of pain. Pain, as a matter of fact, was seldom an important factor (Table III). In the face of these contradictions, the series was evaluated according to the recommendations made by Santee.

In 1924, Santee pointed out that after fractures of the upper end of the humerus, disability is usually manifested by loss of strength and by loss of abduction and rotation. He recommended that the range of motion be evaluated according to the following criteria.

1. Abduction is measured in degrees, with the scapula fixed. (Santee did not make specific mention of the number of degrees of abduction necessary for a good result; we consider the range of abduction good if the patient can, with the scapula fixed, abduct his arm 60 degrees.)

2. External rotation is first determined with the shoulder in maximum abduction and

with the elbow flexed. The range of external rotation in abduction is considered good if the forearm moves up to or on beyond the plane of the body.

3. External rotation is next determined with the arm adducted and the forearm flexed. The range of external rotation in adduction is considered good if it permits 20 degrees or more of external rotation beyond the sagittal plane.

4. Internal rotation, determined in the abducted position with the forearm flexed, is considered good if the forearm can be brought down to a point 45 degrees below the horizontal.

A shoulder which permits this range of motion affords the patient sufficient external rotation so that he can place his hand on the back of his head and sufficient internal rotation to place his hand against his back at the sacro-iliac joint on the same side. Such a range of motion allows him to carry out all reasonable and normal activities, provided that strength and endurance are adequate and that pain is minimal. No patient in this study was considered to have had a satisfactory result unless he could perform these motions, exhibited good strength and endurance, and had very little or no pain. We judged an excellent result to be one in which shoulder motion and function were normal or nearly so, and an unsatisfactory result, one in which the range of motion was less than that described. A failure, of course, was one in which motion, strength, endurance, and degree of pain were disappointing.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Preoperative roentgenogram made March 23, 1953 showing Type I-A fracture of head of humerus in Patient 3.

Fig. 1-B: Roentgenogram made March 30, 1953 showing appearance following manipulative reduction.

Fig. 1-C: Anteroposterior roentgenogram made February 15, 1956, six years following reduction, showing maximal scapulohumeral abduction. Acromionectomy has been performed. Note absence of degenerative changes in humeral head. The result was unsatisfactory due to residual humerus varus, severe anteversion and marked limitation of motion.

FIG. 1-C

The result, in addition to being influenced primarily by the severity of the bone injury,

is also affected by many other factors. These include primary local soft-tissue injury, particularly tendinous injury, injuries elsewhere in the body, the patient's age and general health, and, by no means of least importance, the patient's willingness to work to regain good strength and motion in the injured joint. Most of our patients returned to their jobs in from twelve to sixteen weeks; improvement continued for an average of one year. A result can usually be determined with fair accuracy at the end of one year following injury, but in several instances necrosis and collapse of the humeral head progressed for a considerably longer period of time. No patient in this study exhibited delayed complications of either the nervous or vascular systems. Whenever open reduction was performed, its purpose was to restore the disrupted structures to as near their normal anatomy and

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Patient 7. Preoperative roentgenogram made August 26, 1952 showing Type I-A fracture of head with involvement of tuberosities and neck of humerus and severe medial displacement of shaft of humerus.

Fig. 2-B: Anteroposterior roentgenogram made September 23, 1952 following open reduction.

Fig. 2-C: Roentgenogram made February 14, 1956 showing resultant failure due to inadequate fixation and non-union in varus position. Note circulatory changes in humeral head.

function as possible—at the very least, to recreate an articulation which might function painlessly and with reasonable efficiency.

ANALYSIS OF CASES

Group I-A: This group consisted of eight patients in whom there was one major, cartilage-covered fragment of the humeral head still articulating with the glenoid cavity of the scapula, without dislocation. Two patients were treated by simple immobilization, four by manipulation, and two by open reduction. In this group of eight patients, the results were as follows: one excellent, three satisfactory, three unsatisfactory (Figs. 1-A through 1-C), and one failure due to non-union. In one, there was a moderate degree of avascular necrosis of the humeral head with roughening of the joint; in another, treated by manipulation only, there was a rather

severe degree of avascular necrosis of the humeral head. Of the two patients treated by open reduction, one had a mild degree of avascular necrosis of the humeral head but a satisfactory result; the other had a moderate degree of avascular necrosis, and non-union of the major fragment; the result there, of course, was failure (Figs. 2-A, 2-B, and 2-C). We believe that, if the fragments can be properly aligned without elevation of the tuberosities and without a varus deformity, one can generally expect a satisfactory result (Table IV).

Group I-B: In this group of seven patients, there was more severe comminution of the fragments of the humeral head than in Group I-A. Three were treated by simple splint immobilization (Figs. 3-A, 3-B, and 3-C), two by manipulation, one by open reduction with an excellent result, and one by resection of the head and distal transplantation of the rotator-cuff attachments (the Jones procedure[5, 6]) with an unsatisfactory result (Figs. 4-A, 4-B, and 4-C). All of the patients showed avascular necrosis of mild or moderate degree. In all but the one patient who had the open reduction, and of course the one treated with the Jones procedure, there were varying degrees of arthritic degeneration, absorption, and even marked flattening of the humeral head. Two patients had pain of significant degree: one had had manipulation and one had not. No conclusions can be drawn, for the group is small. It is apparent, however, that some degree of avascular necrosis occurs in a large proportion of patients with comminuted fractures of the humeral head. Fortunately, this complication does not impair shoulder function to the same degree that it impairs hip function after fractures of the neck of the femur (Table IV).

FIG. 3-A

Fig. 3-A: Roentgenogram made of Patient 11 August 1, 1954 showing a Type I-B fracture. The humeral head is "split" and there is medial displacement of the shaft.

Fig. 3-B: Anteroposterior roentgenogram with arm at side, made March 6, 1956, nineteen months after injury. The fracture is consolidated, but displacement persists. Motion is extremely limited and painful.

Fig. 3-C: Anteroposterior roentgenogram made March 6, 1956 with arm in maximal abduction. There are 14 degrees of scapulohumeral abduction. The result would have been better had open reduction been possible, but the patient's condition precluded surgery.

FIG. 3-B

FIG. 3-C

TABLE IV

GROUP ANALYSIS OF CASES

Patient	Age	Sex	Procedure	Pain	Roentgenographic Appearance: Scapulo-humeral Abduction (*Degrees*)	Roentgenographic Appearance: Avascular Changes in Humeral Head (*0, 1, 2, 3*)	Roentgenographic Appearance: Other Changes in Humeral Head	Patient's Evaluation	Examiner's Evaluation
					Group I-A				
1	34	M	Immobilization	0	67	0	None	S	E
2	76	F	Immobilization	0				S	S
3	62	F	Manipulation	3	46	0	Severe varus	U	U
4	60	F	Manipulation	2	48	1	Joint roughening	U	U
5	63	F	Manipulation	2		3	Degeneration	U	U
6	68	M	Manipulation	0	28	0	Mild varus	S	S◇
7	37	M	Open reduction	2		2	Non-union	U	F
8	57	F	Open reduction	1	12	1	Degeneration	S	S
					Group I-B				
9	45	F	Immobilization	3	39	1	Arthritis	U	U◇
10	75	F	Immobilization	0	17	2	Degeneration	S	U
11	74	F	Immobilization	1	14	1	None	S	S
12	72	F	Manipulation	1		2	Absorption	U	U
13	52	M	Manipulation	2	12	1	Absorption	U	U
14	71	F	Open reduction	0	50	1	None	S	E
15	49	M	Jones	0	5			U	U
					Group II-A				
16	82	F	Manipulation	0	34	0	Mild varus	S	S◇
17	57	F	Manipulation	0	78	1	None	S	S
18	51	F	Open reduction△	1	15	1	None	S	U
19	46	M	Open reduction	0	12	3	Absorption	S	U◇
20	49	M	Open reduction	0	53	2	Moderate absorption	S	S
21	51	M	Open reduction△	0	67	1	Mild varus	S	S◇
22	49	F	Open reduction†	0	94	0	None	S	E
23	36	F	Open reduction†	1	10	2	Non-union	U	F
24	54	F	Open reduction†	0		1	None	S	E
25	55	F	Open reduction	0		1	None	S	S◇
26	64	F	Open reduction	0	7	2	None	U	U◇
27	28	M	Open reduction†	0		1	None	S	S
28	58	F	Open reduction	0	0	0	Postoperative infection	S	F
29	39	M	Open reduction	0	14	2	Marked absorption	S	S
30	50	F	Resection	0	15			U	F
31	64	F	Jones	2	10			U	F‡
					Group II-B				
32	59	F	Manipulation	0		2	Absorption	S	S
33	58	F	Open reduction	0		2	None	S	E
34	56	M	Open reduction	0	18	2	Degeneration	U	U◇
35	63	M	Open reduction	1	9	1	Cystic	U	U◇
36	56	M	Jones	2	17			U	F
37	40	M	Jones	0				S	S
38	75	F	Jones	1	8			S	S
39	46	M	Jones	0				S	S
40	79	F	Jones	2				U	F

S = Satisfactory
U = Unsatisfactory
E = Excellent
F = Failure

◇ Would be benefited by acromionectomy
△ Manipulation failed
† Posterior dislocation
‡ Joint dislocated postoperatively

FIG. 4-A

FIG. 4-B

Fig. 4-A: Roentgenogram made of Patient 15 October 6, 1949, showing a Type I-B fracture with "split" head and with complicating oblique fracture of neck of the humerus.

Fig. 4-B: Roentgenogram made June 13, 1955 showing unsatisfactory result following Jones procedure. Note clinical fibrous ankylosis of shoulder in poor functional position.

Fig. 4-C: Lateral roentgenogram made June 13, 1955 showing humerus lying posterior to glenoid cavity. Note bone proliferation anterior to upper humeral shaft.

FIG. 4-C

Group II-A: Group II, it is recalled, is composed of fracture-dislocations, the fractures in Subgroup A being less severely comminuted than those in Subgroup B. In Group II-A there were sixteen patients. The fracture was impacted in only two of these; in four the dislocations were posterior. Two patients were treated by manipulation, both with satisfactory results. One was treated by simple resection of the humeral head and one by the Jones procedure; in these two the results were complete failures. The remaining twelve patients were treated by open reduction (Figs. 5-A through 6-C), with the following results. In two the results were excellent and in five they were satisfactory. In three patients the results were unsatisfactory. Although two of these patients were completely satisfied, their examiner was not. Results in two were failures; in one of these patients there was non-union, in the other there was a postoperative infection. Only three of the fourteen patients in whom the humeral head was preserved failed to show some degree of avascular necrosis. In most instances, however, it was mild and in no instance did it significantly impair the result. It is of interest that only two of the twelve patients who had open reduction of the fracture-dislocation complained of pain; in neither was it severe or disabling (Table IV).

Group II-B: Of the nine patients in this group, one was treated by manipulation, three by open reduction (Figs. 7-A, 7-B and 7-C), and five by the Jones procedure (Figs. 8-A through 9-D). An open reduction produced one excellent result; in the remainder

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: Roentgenogram made August 14, 1953 of Patient 19, showing a Type II-A fracture-dislocation of the shoulder.

Fig. 5-B: Roentgenogram made September 18, 1953, one month following open reduction and internal fixation.

Fig. 5-C: Roentgenogram made May 8, 1956, two years and nine months after operation. There was no pain. Examination revealed 45 degrees of clinical abduction of the arm on the trunk, though but 12 degrees of scapulohumeral abduction. The result was satisfactory to patient but not to examiner.

of the group there were four satisfactory results, two unsatisfactory, and two failures (Table IV).

DISCUSSION

In this series, avascular necrosis and degenerative changes in the humeral head were a frequent finding, both in those patients who had been operated upon and in those who had not. Although no statistically valid conclusions can be drawn, it appears that open reduction does predispose toward avascular necrosis, but not to a striking degree. There was no apparent correlation between strength, degree of pain, and avascular necrosis. There was, likewise, no correlation between age and results. And, as has been said, some patients were satisfied with the functional result even when the examiner was not.

Acromionectomy was employed only once as a primary procedure and only twice as a secondary procedure (Fig. 1-C). We now believe that the results would have been materially better in several patients had acromionectomy been performed at the time of original operation.

Fig. 6-C: Roentgenogram made February 14, 1956 showing satisfactory result nine years later, with arm in position of abduction. The patient exhibited 53 degrees of scapulohumeral motion and had no pain despite degenerative and absorptive changes in the humeral head.

Fig. 7-A: Patient 35. Roentgenogram made July 8, 1953 showing Type II-B anterior fracture-dislocation. Open reduction was performed but no internal fixation used; displacement and deformity recurred.

Fig. 7-B: Anteroposterior roentgenogram made February 28, 1956 of shoulder with arm at side, two and one-half years after injury. Function unsatisfactory: the patient could not place his hand behind his back, and could barely place his hand behind his head.

Fig. 7-C: Anteroposterior roentgenogram made February 28, 1956 with arm in abduction. The patient had 9 degrees of scapulohumeral abduction and very little pain.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Patient 20. Roentgenogram made December 18, 1946 showing a Type II-A fracture-dislocation of the shoulder.

Fig. 6-B: Anteroposterior roentgenogram made December 30, 1946 following open reduction. Internal fixation was not required.

FIG. 6-C

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 8-A

FIG. 8-B

Fig. 8-A: Patient 36. Roentgenogram made March 29, 1949 showing Type II-B anterior fracture-dislocation of the humeral head.

Fig. 8-B: Roentgenogram made May 30, 1949, two months after Jones procedure. Note bone proliferation.

FIG. 8-C

FIG. 8-D

Fig. 8-C: Anteroposterior roentgenogram made March 30, 1956, seven years after operation, with arm in maximal abduction. There were 17 degrees of scapulohumeral motion. Note adaptive degenerative changes of upper end of humerus at articulation with the glenoid cavity.

Fig. 8-D: Lateral roentgenogram made March 30, 1956 showing bone proliferation both anteriorly and posteriorly. The result was failure.

The Nicola tenodesis was carried out as a stabilizing procedure in five patients who had open reduction and in one of the eight who had a resection of the humeral head. The hour-glass constriction mentioned in the literature as a rather frequent and serious complication of simple shoulder-joint resection was not encountered in this series. The Jones procedure was used in seven of the eight patients who had resection of the humeral head in order to restore active scapulohumeral-muscle control. Perhaps this addition to the simple resection technique serves to avoid that complication. However, despite the cuff transplantation, the over-all functional result of the Jones procedure was disappointing: the result was satisfactory in three patients, unsatisfactory in one, and a total

FIG. 9-A

FIG. 9-B

Fig. 9-A: Patient 37. Roentgenogram made March 19, 1945 showing Type II-B anterior fracture-dislocation of the humeral head.

Fig. 9-B: Roentgenogram made June 8, 1945 showing early result after Jones procedure. Note bone proliferation.

FIG. 9-C

FIG. 9-D

Roentgenograms made February 13, 1951 showing satisfactory result six years after operation. Note range of scapulohumeral abduction.

failure in three. Still, it is to be remembered that this group of patients had irreparable damage to the humeral head and that this is a salvage procedure. It is, then, particularly in this group of patients in whom comminution of the humeral head is so severe that reassembly is impossible or unwise, that the prosthetic procedure may prove superior. This is the same conclusion that Neer reached.

Neer recommended that immediate replacement of the proximal humeral articulation should be considered in these three situations: fracture-dislocation with extrusion of the head; impression fracture involving more than 50 per cent of the articular surface; and comminuted fracture of the articular dome (the "head-splitting" fracture of Dehne), which corresponds to the injuries in our Group I-B.

This review of our patients does not, however, lead us to believe that comminution of the humeral head or even dislocation of the head fragment is a positive indication for the

TABLE V

END RESULTS

Patient's Rating		Per cent
Satisfactory		60
Unsatisfactory		40
Examiner's Rating		
Excellent	5 patients	50
Satisfactory	15 patients	
Unsatisfactory	13 patients	50
Failure	7 patients	
Total	40	

insertion of a prosthesis. The results of open reduction and internal fixation of the fragments, although far from providing normal shoulder function, are satisfactory to the patient in a relatively high percentage of cases and to the physician in a reasonably good percentage of cases. Thus, prosthetic arthroplasty would have to yield definitely improved results over a long period of time to justify its routine substitution for open reduction and internal fixation.

SURGICAL TECHNIQUE

During the course of this study, some techniques were found to be of value, and some errors in technique became apparent:

1. The saber-cut approach of Codman, or one of its modifications [9], is preferable to the anterolateral approach of Thompson and Henry since it affords a more complete exposure of the humeral head and the rotator cuff of the shoulder.

2. A cautery knife should be used, and adequate hemostasis should be obtained as the operation proceeds.

3. Adequate buried internal fixation is preferable to removable-pin transfixion. Removable pins, even though threaded, may migrate, and the fixation they afford is frequently undependable. Pin-track infections may develop when pins and wires are permitted to protrude through the skin.

4. Varus deformity is undesirable and should be avoided.

5. We have found no evidence that the Nicola tenodesis is of value in conjunction with open reduction or resection. We encountered no patient with signs or symptoms of bicipital tenosynovitis.

6. A generous portion of the acromion should be excised to minimize impingement of the humerus on the scapula.

7. The origin of the deltoideus muscle should be meticulously reattached to the clavicle and to the stump of the acromion by means of interrupted sutures through holes drilled in both bones. In a disappointingly high percentage of shoulders in this series, the anterior portion of the deltoideus was either poorly reattached or not reattached at all, and its function was weakened to a corresponding degree.

8. A comfortable abduction splint should be prepared before operation for application immediately following closure of the wound.

CONCLUSIONS

1. Fractures and fracture-dislocations of the articular surface of the humeral head are severely disabling.

2. Pain is seldom a significant factor in the result (Table III). Rather, weakness, limitation of motion, and reduced endurance are the usual complaints.

3. The patient is more often satisfied with the result than is the orthopaedic surgeon who has treated him (Table V).

4. The result must be evaluated by a realistic set of criteria. Even so, the results of treatment in this study were acceptable to the examiners in only 50 per cent of the cases, and to the patients in 60 per cent of the cases.

5. Results might be improved by following the recommendations made regarding surgical technique.

6. The insertion of a prosthesis, although not yet conclusively demonstrated to be effective in solving the problems raised by this injury, is most logically considered for use in that group of comminuted fractures and fracture-dislocations which, in this series, have been treated by resection or by resection and cuff transplantation. Should the long-term results be superior, the use of a prosthesis may conceivably be advisable in the treatment of the more severely comminuted fractures of the humeral head which are now being treated by open reduction.

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Procedure for Bone Sterilization with Beta-Propiolactone

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Since there is an ever increasing demand for sterile-tissue homogenous transplants in the field of surgery and since autopsy material is the most likely source for homogenous transplants, a simple, inexpensive, and safe procedure for sterilizing tissue is greatly needed. The elaborate aseptic technique employed in obtaining sterile tissue in certain medical centers not only is expensive and, therefore, confined to isolated institutions but also is unsafe as regards sterility. The removal of all microbiological pathogens must be ensured when human tissue obtained from autopsy material is used. The usual practice of testing for bacterial and mycotic contamination overlooks the potential hazards of virus infection, malignant growth, and parasitic infection. Moreover, it is not sufficient to eliminate the cadavera of all persons who were known to have had malignant or febrile conditions prior to death, for the person whose cadaver is used may have had an undiagnosed latent parasitic condition still in the carrier state. The well known hepatitis agent which is associated with blood transfusions [15] and the transmissible, probably viral, agent in human blood recently described by Beutler and Dern are examples of conditions which must be looked for whenever blood, blood products, and tissue are to be used in homologous transfer.

A human-artery bank, containing autopsy material sterilized by beta-propiolactone, has been maintained at the Henry Ford Hospital since October 1953. Arteries from this bank have been used as transplants in 268 operations without bacterial infection or hepatitis.

The findings of our series of animal experiments are presented to demonstrate the efficacy of beta-propiolactone as a means to inactivate or kill viruses, leukaemia-infected cells, and bacteria in infected tissues. The depth of beta-propiolactone sterilization and a method for applying this sterilization to bone obtained from autopsy material are described.

MATERIAL AND METHODS

The efficacy of beta-propiolactone in sterilizing various types of infected materials was demonstrated by the experimental treatment of the following infected tissues.

1. *Tissues infected by emersion in heavy suspensions of bacterial cultures:* The strains used were *Escherichia coli*, *Bacillus proteus*, *Streptococcus pyogenes*, enterococcus, *Staphylococcus aureus*, and *Bacillus anthrax*. The organisms had been recently isolated from clinical material in the diagnostic laboratory. Desiccated *Bacillus globigii* spores were also used. All the strains were employed in eighteen-hour broth cultures of more than one million organisms per milliliter. Various thicknesses of cancellous bone were placed in these suspensions for two to eighteen hours at 37 degrees centigrade. Segments of abdominal aorta were injected with suspensions of *Bacillus anthrax*. Following infection the tissues were treated with beta-propiolactone.

2. *Infected tissues obtained from animals with bacteraemia:* Swiss albino mice, weighing sixteen to twenty grams, were infected intraperitoneally with Type III pneumococci and twenty-four hours later were sacrificed. Rabbits, weighing five to six pounds, were infected intravenously with five milliliters of *Escherichia coli* suspension containing one to ten billion organisms per milliliter and were sacrificed immediately.

3. *Infected tissues obtained from animals with viraemia:* Three viruses—the strain which causes lymphocytic choriomeningitis, the MM strain which causes encephalomyocarditis, and the strain which causes the eastern type of equine encephalomyelitis—were prepared as 10 per cent mouse-brain suspensions in 10 per cent sheep serum in normal saline. Guinea pigs, weighing 250 to 350 grams, were infected by means of intramuscular injections of the lymphocytic choriomeningitis virus. During the stage of viraemia (four days after injection), the animals were sacrificed, and pieces of tissue of varying thicknesses were prepared for treatment with beta-propiolactone. Swiss albino mice, weighing twelve to sixteen grams, were injected in the paw with the MM strain, encephalomyocarditis virus. They were sacrificed during the stage of viraemia (twenty-four hours after injection), and pieces of tissue were removed and tested. Rabbits of two to three pounds were injected intramuscularly with the eastern equine encephalomyelitis virus. The rabbits were sacrificed during the stage of viraemia (twenty-four hours after injection), and portions of the tissues were removed and tested.

4. *Splenic tissue containing a mouse strain of transplantable leukaemia cells obtained from mice:* AK_4 strain of mouse leukaemia * (0.1 milliliter, in varying cell suspensions) was injected intraperitoneally into AK_4 type mice weighing sixteen to twenty grams. The mice were sacrificed five to seven days after infection. The tissue obtained from the infected spleens of these animals showed that in the circulating blood stream there were 80,000 or more white cells per cubic millimeter of tissue.

Beta-propiolactone

The chemical agent, specially purified beta-propiolactone $(CH_2CH_2C = O)$, is a stable liquid in its concentrated state but is unstable in aqueous solutions. It has a specific gravity of 1.149 and is 37.5 per cent (by volume) soluble in water at 25 degrees centigrade. It reacts readily with hydroxyl, amino, carboxyl, sulphydryl, and phenol, all of which are associated with proteins[2, 3, 4, 5]. Although beta-propiolactone is an irritant and is a toxic agent in its lactone form, it hydrolyzes completely to relatively non-toxic products[6, 10, 14] after two hours at a temperature of 37 degrees centigrade, the conditions for sterilization.

Preparation of Solutions

A saline-bicarbonate solution is first made. This solution contains 0.2 molar sodium bicarbonate (1.68 grams per 100 milliliters of solution) and phenol red indicator (one milligram per 100 milliliters of solution) in isotonic saline (0.85 gram per 100 milliliters of solution). It need not be sterile when freshly prepared. The desired quantities of salt are each prepared in dry test tubes or in papers and added to distilled water. Phenol red indicator from a 1 per cent stock solution is added, 0.1 milliliter per 100 milliliters of solution being used.

A water solution (in which the beta-propiolactone is usually 10 per cent of the water volume) is first made with distilled water chilled to 4 to 5 degrees centigrade, the diluent and drug being kept in an ice bath. This is done in order to slow the rate of hydrolysis as well as to detect whether the beta-propiolactone has deteriorated or polymerized during storage. The drug should form globules when added to water and be readily miscible when vigorously shaken. It is evident that alteration of the beta-propiolactone has occurred if there is crystallization and cloudiness when the drug is added to the ice-cold water. When combined with water at 4 degrees centigrade, a 3 per cent drug concentration will lose approximately 3 per cent of its lactone form in one hour and approximately 7 per cent in four hours. It is therefore practical to prepare a 10 per cent water solution which can be used within a few minutes.

Method for Treating Bacteria-Infected and Virus-Infected Tissues with Beta-propiolactone

All infected tissues were cut into thicknesses varying from one to nine millimeters.

* Obtained from the Sloan-Kettering Institute for Cancer Research, New York, N. Y.

TABLE I

BONE SEGMENTS CONTAMINATED WITH BACTERIA AND TREATED WITH 1 PER CENT BETA-PROPIOLACTONE

Experiment No.	(*Thickness of Specimens in Millimeters*)					
	1	2	3	6	9	12
1	2/2*	2/2	2/2	2/2	1/2	0/2
2	3/3	3/3	3/3	3/3	1/3	0/3
3	2/2	2/2	2/2	2/2	2/2	0/2

* The numerator indicates the number of segments sterilized by the procedure and the denominator indicates the total number of segments contaminated.

Preliminary tests indicated that tissues over nine millimeters in thickness could not be sterilized consistently.

Only one strength of beta-propiolactone (1.0 per cent) was used in the saline-bicarbonate solution. This concentration was used because it had been found in previous studies [12] that 1.0 per cent beta-propiolactone is 80 per cent, 66 per cent, 50 per cent, and 25 per cent in excess of the concentration required to kill the most resistant bacteria, viruses, fungi, and spores, respectively.

The same procedure was used in the treatment of all infected tissues. Varying thicknesses of tissue (one, two, three, six, and nine millimeters) were placed in the saline-bicarbonate solution with beta-propiolactone added to a 1.0 per cent concentration. Each type of tissue was treated in a separate container, each specimen having been cut in the thicknesses indicated above. After two hours of incubation in a waterbath at 37 degrees centigrade, the individual pieces were removed and tested for sterility.

Bacteria-infected tissues were cultured in thioglycolate broth, the individual pieces being placed in separate tubes. These were observed for seven days. Previous experiments have shown [12] that the degradation products of beta-propiolactone are neither bactericidal nor bacteriostatic and that, therefore, subcultures are not necessary.

Virus-infected tissues were prepared as 10 per cent suspension in 10 per cent rabbit-serum saline solutions and assayed for virus activity in mice. Often several pieces of the same thickness were used together in order to obtain an adequate suspension.

Leukaemic tissues from infected spleens were prepared in saline suspensions. Sufficient pieces of the same thickness were used to obtain one million leukocytes per 0.1 milliliter of volume. Tenfold serial dilutions were then made and the infective activity of the cells determined by assay in the AK_4 strain of mice.

Non-treated tissues as control material were handled under parallel conditions without the use of beta-propiolactone.

RESULTS

Tissues Infected by Emersion in Heavy Suspensions of Bacterial Cultures

Pieces of varying sizes of cancellous bone, contaminated by the method described, were treated with 1 per cent beta-propiolactone saline-bicarbonate solution and incubated for two hours at a temperature of 37 degrees centigrade. Table I shows the results of the treatment on segments contaminated for eighteen hours. Each bone segment was approximately one centimeter wide by three centimeters long with thicknesses varying from one to twelve millimeters. After treatment, the segments were removed and separate cultures were made. In three experiments, all bone contaminated in this manner was shown to be sterile if the pieces were not more than six millimeters thick.

Three segments of human abdominal aorta contaminated by multiple injections of *Bacillus anthrax* were similarly treated with beta-propiolactone. In two experiments these were also shown to be sterile by the standard sterility tests for bacteria and fungi.

TABLE II

STERILIZATION OF TISSUES OBTAINED FROM MICE WITH PNEUMOCOCCUS (TYPE III) BACTERAEMIA

Tissue	Presence of Bacteria after Seven Days (*Thickness of Specimens in Millimeters*) 1	2	3	6	Bacterial Count per Gram of Tissue in Controls
Liver	0*	0	0	+	7×10^4
Kidney	0	0	0	+	9×10^5
Bone	0	0	NT	NT	
Artery	NT	0	NT	NT	

* *0* indicates negative-culture results; + indicates positive-culture results; *NT* means not tested.

Tissues Obtained from Animals with Bacteraemia

The described methods of tissue contamination do not take into account infection by means of the blood stream in which the micropathogens invade the entire tissue. For this reason specimens one to six millimeters thick were obtained from the livers, kidneys, bones, and arteries of animals with pneumococcus (Type III) bacteraemia (contaminated as previously described) and were treated with beta-propiolactone. In this test the depth

TABLE III

STERILIZATION OF TISSUES OBTAINED FROM RABBITS WITH *Escherichia coli* BACTERAEMIA

Tissue	Presence of Bacteria after Seven Days (*Thickness of Specimens in Millimeters*) 1	2	3	6	9	Bacterial Count per Gram of Tissue in Controls
Liver	0*	0	0	+	+	22×10^6
Kidney	0	0	0	+	+	8×10^6
Muscle	0	0	0	0	+	
Bone	0	0	0	0	+	
Artery	0	0	0	NT	NT	

* *0* indicates negative-culture results; + indicates positive-culture results; *NT* means not tested.

of beta-propiolactone penetration and sterilization could be ascertained. Table II summarizes the results of three experiments involving thirty-six mice. Sterility tests indicated that the liver and kidney specimens three millimeters thick could be sterilized but that specimens six millimeters thick could not be sterilized. The bones and arteries of mice

TABLE IV

STERILIZATION OF TISSUES OBTAINED FROM ANIMALS WITH VIRAEMIA

Virus	Animal	Specimen	Virus Titer (LD_{50})* Before Treatment	After Treatment
MM strain, encephalomyocarditis virus	Mouse	Artery	3.6	0.0
		Bone	2.5	0.0
Lymphocytic choriomeningitis virus	Guinea pig	Artery	3.9	0.0
		Bone	3.0	0.0
Eastern equine encephalomyelitis virus	Rabbit	Artery	4.4	0.0
		Bone	2.9	0.0

* Reciprocals of negative log of virus dilution; assayed intracerebrally in mice.

TABLE V

STERILIZATION OF SPLENIC TISSUE FOLLOWING INFECTION WITH MOUSE LEUKAEMIA (AK_4)

Chemical Agent	Tissue Thickness (*Millimeters*)	Morbidity Ratio *Cell Count per 0.1 Milliliter of Tissue Suspension* 10^6	10^5	10^4	10^3	10^2	Results
None		6/6*	5/6	6/6	6/6	6/6	Infective
1% beta-propiolactone	1	0/6	0/5	0/6	0/6	0/6	Non-infective
	2	0/6	0/6	0/4	0/6	0/5	Non-infective
	3	0/6	0/6	0/5	0/6	0/6	Non-infective
	6	6/6	6/6	5/5	4/5	0/6	Infective
	9	6/6	6/6	6/6	6/6	6/6	Infective

* The numerator indicates the number of mice that showed infection and the denominator indicates the total number of mice used in each category.

are too small to obtain specimens more than two millimeters thick; what was tested was sterilized. The bacterial count in the non-treated tissues demonstrated adequate infection.

Table III summarizes two experiments of a similar type in which *Escherichia coli* were injected into eight rabbits. In these experiments tissues up to nine millimeters in thickness could be used. At least two, and often three, pieces were tested from each container. Again sterilization of liver and kidney tissues that were more than three millimeters thick could not be obtained. Although in this experiment muscle specimens six millimeters thick were sterilized, this is not a consistent finding. Cancellous bone, a less compact tissue, was consistently sterilized at a thickness of six millimeters, but sterilization of tissues of nine millimeters thick was inconsistent. Arteries were sterilized at their greatest thickness, which was three millimeters. Again the bacterial count of the control tissue was adequate.

Infected Tissues Obtained from Animals with Viraemia

Table IV demonstrates tissue sterilization with beta-propiolactone following viraemia. In two experiments thirty-six mice, twelve guinea pigs, and eight rabbits were infected with MM strain, encephalomyocarditis virus, lymphocytic choriomeningitis virus, and eastern equine encephalomyelitis virus (as previously described). Specimens three millimeters thick or less were then obtained and sterilized with beta-propiolactone. Virus activity was assayed before and after treatment. All the tissues demonstrated adequate infection and sterilization.

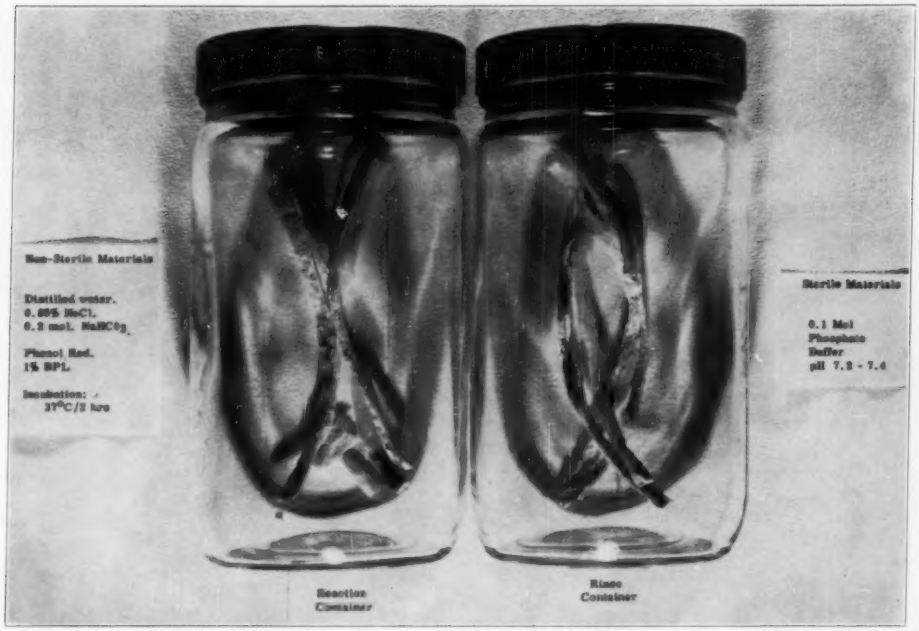
Splenic Tissue with Transplantable Leukaemic Cells Obtained from Mice

In two experiments, splenic tissues obtained from twenty-four mice infected with

TABLE VI

ORGANISMS CULTURED FROM SIXTEEN AUTOPSY SPECIMENS

Type of Organism	No. of Specimens
Aerobacter aerogenes	12
Escherichia coli	10
Enterococcus	10
Bacillus proteus	7
Candida albicans	7
Alcaligenes faecalis	4
Staphylococcus albus	3
Bacillus subtilis	2



Materials and method for beta-propiolactone sterilization of bone.

AK_4 strain of mouse leukaemia (as previously described) were treated with beta-propiolactone. The specimens were from one to nine millimeters thick. The infectivity of the treated tissues was assayed, and it was found that specimens six to nine millimeters thick remained infective whereas those three millimeters thick or less were consistently non-infective (Table V).

APPLICATION OF EXPERIMENTAL RESULTS TO STERILIZATION OF BONE

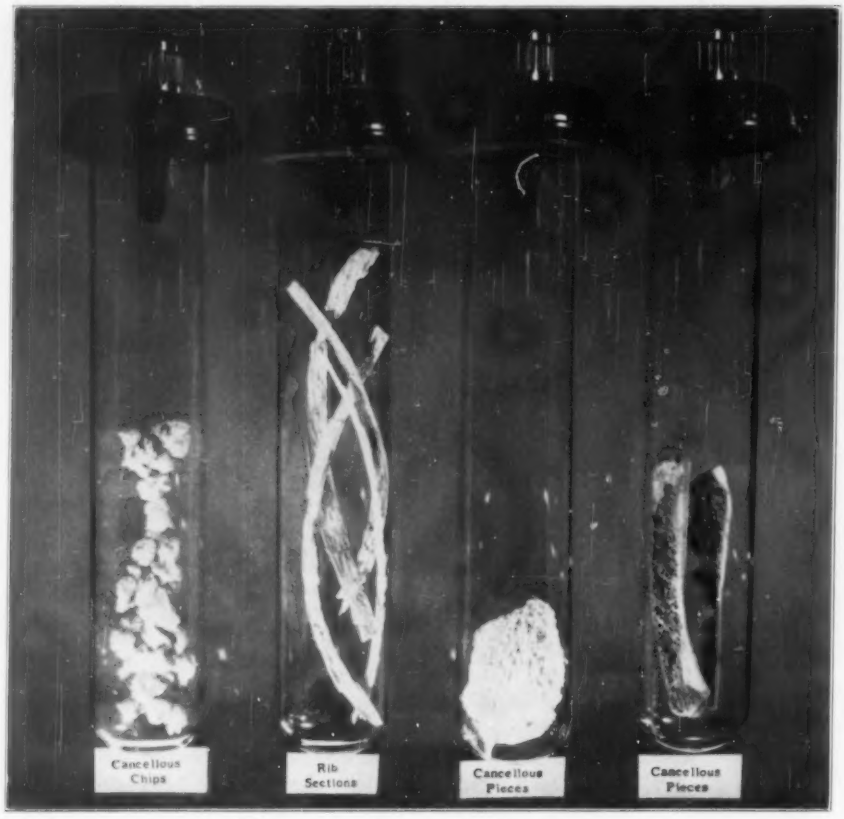
Procedure

Bone material is obtained from the autopsy room without aseptic precautions. Usually ribs, iliac crests, and vertebral bodies afford an ample supply of cancellous and cortical bone. All the bones are cleaned of soft tissue and periosteum without aseptic technique. They are then prepared as cancellous chips, rib sections, and cancellous pieces. It is important that only one surface of each piece is cortical bone. The length and width may vary, but the thickness should not exceed six millimeters.

The bone is sterilized in three steps:

1. The prepared pieces of bone are placed in a clean, wide-mouth, screw-cap glass jar which is approximately eight by sixteen centimeters in size (Fig. 1). This container is kept in an ice bath. As isotonic saline solution (225 or 450 milliliters, depending upon the amount of bone), previously chilled to 4 to 5 degrees centigrade, is put into the jar; 0.3 milliliter of 1 per cent phenol red indicator and sufficient powdered sodium bicarbonate are added to make a 0.2 molar solution (4.2 grams and 8.4 grams for 225 milliliters and 450 milliliters, respectively).

2. A 10 per cent solution of beta-propiolactone is prepared just prior to use. The concentrated beta-propiolactone solution (specific gravity, 1.149) and the distilled water are always kept in an ice bath to prevent hydrolysis. First 2.2 (or 4.4) milliliters of concentrated beta-propiolactone is placed in a twenty-five (or fifty) milliliter volumetric flask. Cold distilled water is then added to make twenty-five (or fifty) milliliters of 10



Variety of bone and method of storage. Specimens are lyophilized and stored at room temperature.

per cent drug solution, and the flask is vigorously shaken until the drug globules go into solution. Following this the twenty-five (or fifty) milliliters of 10 per cent beta-propiolactone is rapidly added to the 225 (or 450) milliliters of saline-bicarbonate solution to give a final concentration of 1 per cent beta-propiolactone. It is imperative to shake the beta-propiolactone solution vigorously for a few seconds in the closed container in order to sterilize the screw cap and rim of the jar as well as the bone.

3. The mixture, with the emersed pieces of bone, is incubated at 37 degrees centigrade for two hours in a water bath or for three hours in an incubator. It is well to bear in mind that after incubation beta-propiolactone is completely hydrolyzed and that the products of hydrolysis are not bactericidal, fungicidal, or virucidal [12].

The bone specimens must now be handled aseptically. The mouth of the container is flamed; and the pieces are taken out of the jar under an ultraviolet hood, washed in a 0.2 molar, sterile, phosphate buffer solution (pH 7.2 to 7.4) for a few minutes (Fig. 1), and transferred to suitable sterile storage containers (Fig. 2). Routine sterility tests are conducted on the fluid which drains from the specimens in each container. The sterilized bone is stored in the deepfreeze unit. Specimens may be treated by lyophilization and kept at room temperature if desired. For this purpose there are available standard pyrex glass tubes (thirty-six by 200 millimeters) to fit the Fenwall plastic stopper which has a Telovac rubber diaphragm. The stopper has a convenient projection for the rubber-tube attachment used in lyophilization.

Results

The first sixteen specimens obtained by autopsy were tested by culture before and after treatment with beta-propiolactone. Table VI lists the organisms isolated before sterilization. The variety of organisms isolated is not unusual nor is the frequency with which they were found. After treatment with beta-propiolactone and storage for seven or fourteen days, the specimens were found sterile (by cultures for bacteria and fungi).

The clinical results of beta-propiolactone sterilization of bone have been very satisfactory. As of October 1, 1956, specimens from the bone bank had been used in fifty operations. The operative procedures included filling of large cysts, spine fusion for scoliosis and tuberculosis, and grafting to treat fractures, both fresh and old, and to obtain fusion. In general the bone transplants did well. Only one infection was noted in this series (in a case of fracture of the calcaneus treated by open reduction, following which a skin slough developed and infection was present on the thirteenth day); the wound in this case healed without loss of the graft or reduction. Additional data are being accumulated and will be reported at a later date.

SUMMARY

1. One per cent beta-propiolactone has been shown capable of sterilizing animal tissues which have been either artificially infected with vegetative and spore-forming bacteria or taken from the animals during the stage of bacteraemia or viraemia. It also sterilizes leukaemic-infected splenic tissue.

2. The depth of drug penetration did not exceed 1.5 millimeters in compact tissues (liver and spleen) and three millimeters in cancellous bone. Thus, compact tissues to a thickness of three millimeters and cancellous bone to a thickness of six millimeters can be satisfactorily sterilized.

3. Good results were obtained in all of the cases in which beta-propiolactone sterilized bone was used (fifty operations).

4. A bone bank in which material sterilized with beta-propiolactone is used has been established.

5. The simple, rapid, and inexpensive chemical method of the sterilization of contaminated bone described in this paper can be readily utilized in small hospitals.

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Tuberculosis of the Femoral Neck in Childhood

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From the Princess Margaret Rose Hospital, Edinburgh

Tuberculosis of the femoral neck as an isolated focus in young children is a well recognized but rare condition. Dobson, reviewing a series of 320 patients ranging in age from sixteen months to sixty-nine years and suffering from tuberculosis of the hip joint, found only fifteen in whom the site of the primary bone focus was confined to the neck of the femur. Although the pathology and management of extra-articular foci of tuberculosis in the region of the hip joint is discussed by several authors [2, 6, 9], no paper dealing solely with the present subject can be found. The authors cited agree that almost invariably the hip joint is affected sooner or later, regardless of whether the treatment of the bone focus has been conservative or operative. Therefore, in the past, surgery has been considered of doubtful value.

Since the introduction of antibiotics, there has been a dramatic change in the manage-

FIG. 1-A

Case 1. Roentgenograms made on admission of the patient in October 1942.

ment of bone and joint tuberculosis. Mercer recently stated that "chemotherapy has allowed us to return to the more radical methods of local attack, some of which, in years gone by, were disappointing because they were so often followed by sinus formation and dissemination of the disease." Evidence is accumulating of a growing trend for early operation on skeletal tuberculosis [1, 5, 7, 12, 13]; joint disease is being treated by intra-articular operation with the hope of preserving function. Although sufficient time has not yet elapsed for a final assessment of the results of these operations, early reports are encouraging. Wilkinson [13] recently described the immediate results of partial synovectomy and curettage in the treatment of tuberculosis of the hip. All patients were treated by constitutional therapy, antibiotics, and intra-articular operation. Thirty-one recovered with some return of joint function, but operative stabilization was required in eight. Wilkinson [13] concluded that "restitution of joint function is quite possible even after severe dis-

case . . ." and that "operation is especially indicated for patients who have necrotic bone lesions."

The purpose of this paper is to report three patients suffering from an extra-articular focus in the femoral neck who were treated by early drainage and curettage. They were followed for a minimum of ten years, and each retained a mobile hip joint. In these three patients the disease occurred before 1946 and antibiotics were not employed.

CASE REPORTS

CASE 1. A boy aged two and a half years was admitted to the hospital in September 1942, complaining of pain at night in the left hip which had been present intermittently for nine months. No abnormal physical

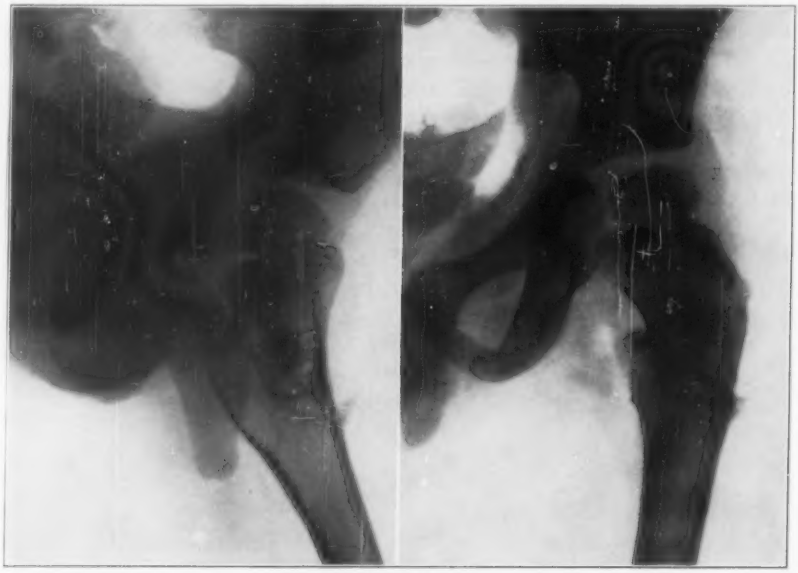

FIG. 1-B

Condition one and a half years after admission.

FIG. 1-C

Roentgenograms made in 1955, thirteen years after operation.

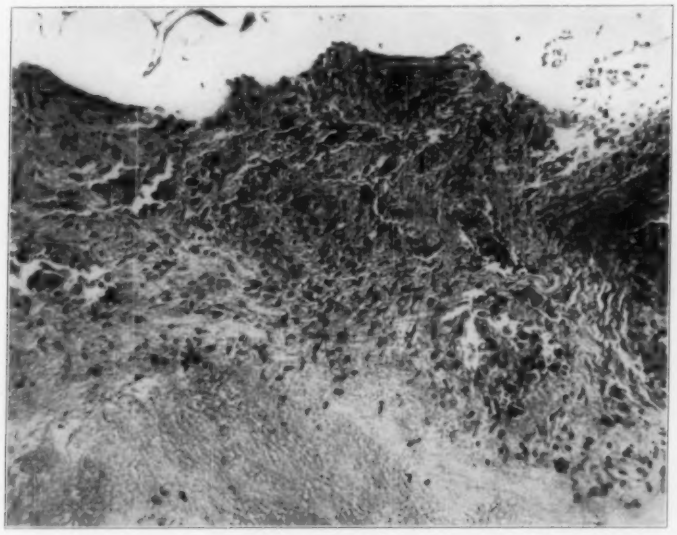

FIG. 1-D

Photomicrograph (× 195) showing necrotic bone bordered by granulation tissue in which there are follicles of epithelioid cells including some small giant cells.

signs were detected, but roentgenograms revealed a well localized, encysted lesion in the inferior aspect of the neck of the femur (Fig. 1-A). He was immobilized on an abduction frame, and early in October 1942 the focus was scraped out. With the child lying on an orthopaedic table, a vertical skin incision was made on the lateral aspect of the thigh centered on the base of the greater trochanter. The muscles were split and the lesion approached from the lateral aspect through a tunnel in the femoral neck, a Smith-Petersen guide wire and roentgenographic control being used. Bone surrounding the wire was excavated with a tiny gouge, and the contents and wall of the cavity were scraped out with a sharp spoon until sound bone was encountered. Periosteum was felt on the anterior wall of the cavity. The wound was closed in layers and the hip was immobilized in a plaster spica for ten months. The boy then used a caliper brace for a further eight months. Roentgenograms in May 1944 revealed that the cavity had filled in well (Fig. 1-B); the caliper was discarded,

FIG. 2-A

Case 2. Roentgenograms made on admission of the patient in September 1944.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Roentgenogram made at operation showing an exploratory bone drill in position.
Fig. 2-C: Condition two and a half years later.

FIG. 2-D

Figs. 2-D and 2-E: Condition five years after operation, showing premature fusion of the epiphysis.

and the boy has had no treatment since. In 1955, thirteen years after the operation, he was leading a normal life, playing intensive games, and had no complaints. There was a full range of movement in the left hip joint, and roentgenograms showed no evidence of the original lesion (Fig. 1-C).

CASE 2. A girl five years old was admitted to the hospital in September 1944. She gave a history of pain in the left knee associated with a limp and occasional night sweats for seven weeks. There was slight wasting of the muscles surrounding the left hip joint, and terminal limitation of movements due to spasm. Roentgenograms showed a localized destructive lesion in the metaphyseal region of the femoral neck on its inferior aspect (Fig. 2-A). In late September 1944 the focus was drained and curetted, a technique similar to that described in Case 1 being used. Roentgenograms demonstrated the exploratory bone drill in position (Fig. 2-B). Caseous tissue was encountered and evacuated. The hip joint was immobilized in a plaster spica for nine months, and the child was fitted with a caliper brace for the next nine months. Use of the caliper was discontinued in March 1946. Roentgenograms in April 1947 revealed that the cavity in the femoral neck

FIG. 2-E

FIG. 2-F

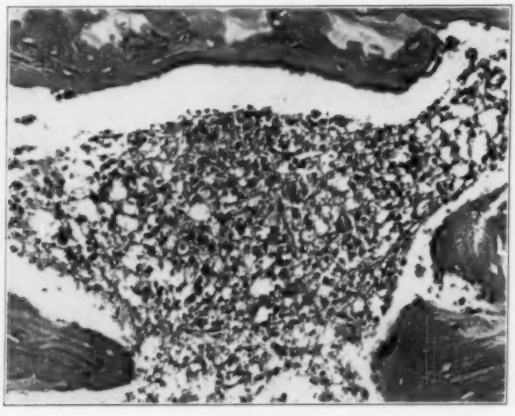

FIG. 2-G

Fig. 2-F: Roentgenogram showing the condition of the patient ten years after operation.
Fig. 2-G: Photomicrograph (× 164) showing necrotic granulation tissue consisting of cells of epithelioid type. There is a tendency to the formation of follicles.

had healed well, but that premature fusion of the epiphyseal line between the head and neck of the femur had begun (Fig. 2-C). By September 1949, this fusion had progressed (Figs. 2-D and 2-E).

In October 1954, ten years after operation, this patient was leading a normal life with no complaints. There was moderate limitation of abduction in the left hip, but the range of the other movements was complete. The left limb was three-quarters of an inch shorter than the right. Roentgenograms revealed an intact hip joint, and no evidence of the original lesion, but the femoral neck was grossly short, and the greater trochanter was above the level of the head (Fig. 2-F).

Arrested growth at the epiphyseal plates is a well recognized condition, but few reports can be found of its occurrence between the head and neck of the femur. Hatcher and Phemister described two cases due to tuberculosis. Ratliff noted a retardation of growth of the femoral neck in at least ten patients with pseudocoxalgia followed up into adult life; in no case, however, was premature fusion at the epiphyseal line proved roentgenographically. Case 2 demonstrates a short femoral neck due to definite fusion of the epiphysis.

CASE 3. In the summer of 1945, a boy aged five began dragging the left limb. This was associated with soreness around the hip. The condition was attributed to an indefinite and apparently minor fall. There was no spasm, and there was a full range of movement in the hip, but in November roentgenographic study

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. Roentgenogram made at operation, January 1946.
Fig. 3-B: Condition of the patient six months later.

FIG. 3-C

Figs. 3-C and 3-D: Roentgenograms made in 1955, almost ten years after operation.

revealed an encysted lesion of the femoral neck. The child was admitted to the hospital in January 1946, and two weeks later the focus was drained and curetted. In this operation clips were employed as markers, but otherwise the operative proc. ure was similar to that in Case 1. Roentgenograms made at the operating table showed the lesion in the center of the femoral neck with the clips in position (Fig. 3-A). The hip was immobilized in a plaster spica for two years. Six months after operation roentgenograms revealed the cavity filling in well, although there was an apparent extension of it into the lower part of the upper femoral epiphysis (Fig. 3-B), which may have been due either to a true extension of the disease or to the operation. After his hip was mobilized, the boy was given a caliper brace for six months. For the past five years he has been leading a perfectly normal life, including playing on his school football team, skating, and cycling. Occasionally, after intensive exercise, he tends to drag the left limb, but otherwise there are no symptoms. There are no abnormal signs connected with the left hip joint except for terminal limitation of abduction and a very mild wasting of the thigh.

Anteroposterior roentgenograms, ten years after the operation, showed no difference between the normal and abnormal hip. In the lateral view the only abnormality seen was some thickening and irregularity of the trabeculae of the femoral neck (Figs. 3-C and 3-D).

FIG. 3-D

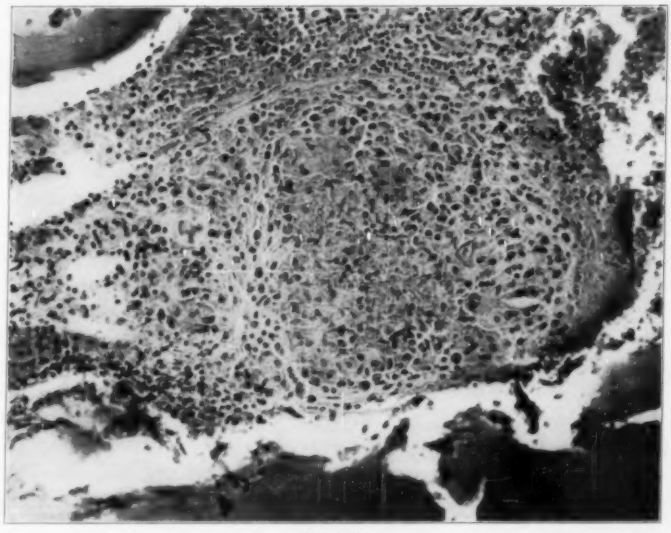

FIG. 3-E

Photomicrograph (× 170) showing a circumscribed follicle closely simulating a tubercle. In consists of a small central zone of necrosis surrounded by epithelioid cells.

HISTOLOGICAL OBSERVATIONS

The diagnosis of tuberculosis was not proved, although it was strongly suggested, by histological examination of the material removed at operation. The characteristic histological features of tuberculous disease are follicle formation with multinucleated giant cells of Langhans' type, lymphocytic infiltration, and varying degrees of granular acellular necrosis. All specimens showed at least two of these diagnostic features, in spite of the sparse and fragmented tissue available for examination. Photomicrographs of tissue removed at operation from each patient are shown in Figures 1-D, 2-G, 3-E, and 3-F. In conjunction with the roentgenographic appearances, no diagnosis other than tuberculosis seems possible.

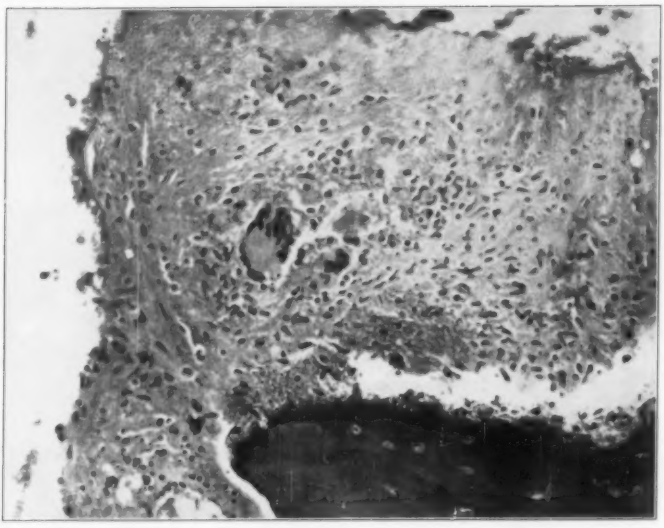

FIG. 3-F

Granulation tissue containing a poorly defined follicle, in which there is a typical Langhans' giant cell, is shown in photomicrograph (× 170).

DISCUSSION

Tuberculosis as a primary focus in the neck of the femur usually occurs as a circumscribed area of bone destruction in the metaphysis (Figs. 1-A and 2-A). Such extra-articular bone foci are seen most often in young children; they are very rarely seen in adults. The infection is borne by the blood stream and characteristically affects a wedge-shaped area upon the undersurface of the femoral neck just distal to the epiphyseal line [4] (Fig. 1-A). In these three patients the symptoms were mild and, except in Case 2, there were no marked physical signs.

I appreciate that no claim can be made which is based on the results of treatment of only three patients. On the other hand, as far as I can trace from the literature, these case records are unique. Hatcher and Phemister reported that a lesion in the femoral metaphysis healed without joint involvement in only two of fourteen children. Both of these were treated conservatively; one required plaster immobilization for seven years. Cholmeley reported that of fifty-five patients with extra-articular foci including those in the ilium, only three recovered with an intact hip joint, although one of these had not been under observation long enough to be considered safe. In none of the three was the lesion in the femoral neck. Ponseti described three patients with a primary lesion in the femoral neck; all of the lesions involved the hip joint sooner or later.

There are two features which may have been of importance in the management of the patients reported here. First, they were operated on within a few weeks of admission to the hospital. Tuberculous lesions in children are often very destructive, and early release of tension may prevent their further spread. Second, the tuberculous focus was drained by a lateral approach up the femoral neck. This method receives scant mention in the literature; no reference has been found in any of the standard textbooks of operative orthopaedics or bone and joint tuberculosis. Robertson Lavalle ascribes the technique to Delbet, but no further details are quoted. This operation is difficult, especially in the small femoral neck of a young child. Nevertheless, restriction of surgery to bone prevents operative contamination of the synovial membrane of the hip joint.

The cessation of growth at the upper femoral epiphysis in Case 2 has already been

noted. No conclusive evidence is available to indicate whether this was due to the disease itself or to operative damage. Nevertheless, in those patients in whom the tuberculous focus is confined to the neck of the femur, it would appear a wise precaution to avoid perforation of the epiphyseal plate at operation. Roentgenographic control should be employed, careful measurements made, and the curette inserted into, but not beyond, the tuberculous focus.

On the other hand, if on initial examination it is seen that the disease already involves the epiphyseal plate, then the risk of damage to this plate at operation would appear unavoidable.

Finally, it is emphasized that these patients were treated before antibiotics were available. Comment on the possible result of treatment with antibiotics is outside the scope of this paper but, on general principles, it is fair to assume that a combination of surgery and chemotherapy would be even more likely to result in an intact hip joint.

NOTE: I am grateful to Mr. R. I. Stirling and Mr. W. V. Anderson for permission to publish these cases, and to them and to Professor Sir Walter Mercer for help and advice in the preparation of this paper. The tissue from these patients was examined by Lieutenant-Colonel W. F. Harvey and Dr. E. K. Dawson at the Royal College of Physicians' Laboratory, Edinburgh. (R.C.P. 4756/42, 6471/44, 5325/46).

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Use of a Prosthesis for the Distal Portion of the Radius Following Resection of a Recurrent Giant-Cell Tumor

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It is now commonly accepted that the true giant-cell tumor tends to recur after attempted eradication and is often aggressive in its behavior[7, 8, 9, 11]. This neoplasm frequently presents a challenge to the surgeon especially when he is trying to preserve the function of the affected part. Such considerations were encountered in the management of the following case.

C. Y., a man twenty-three years old, complained of pain in his right wrist after a fall while playing football on September 20, 1949. The same day he visited the emergency room of Harlem Hospital. He had experienced some discomfort in the wrist for several years prior to the injury. Roentgenograms (Fig. 1) showed an eccentric, radiolucent, expansile lesion of the ulnar side of the distal end of the radius. He was admitted to the hospital and, on September 30, 1949, the lesion was curetted and the resulting cavity was packed with iliac-bone chips. Microscopic sections showed the lesion to be a giant-cell tumor.

The tumor recurred less than one year later. Soft-tissue extension forming a mildly tender fusiform mass on the ulnar side of the dorsum of the wrist was the outstanding feature of the recurrence rather than the bone destruction of the radius (Fig. 2). On July 28, 1950, the distal one-fourth of the radius was resected along with the soft-tissue mass. The proximal portion of the patient's right fibula was removed and implanted into the wrist as a replacement for the resected articular end of the radius. Solid union occurred after four months of plaster-of-Paris immobilization of the wrist although angulation ulnarward took place (Fig. 3). Microscopic sections of the specimen as well as those obtained after the first operation were reviewed by Dr. Henry L. Jaffe. It was his opinion that these showed a giant-cell tumor with some aggressiveness of the stroma (Fig. 4).

Six months after the resection and grafting the patient was able to perform heavy work. However, again within a year there was recurrence of a small mass on the dorsum of the wrist. This grew to a consid-

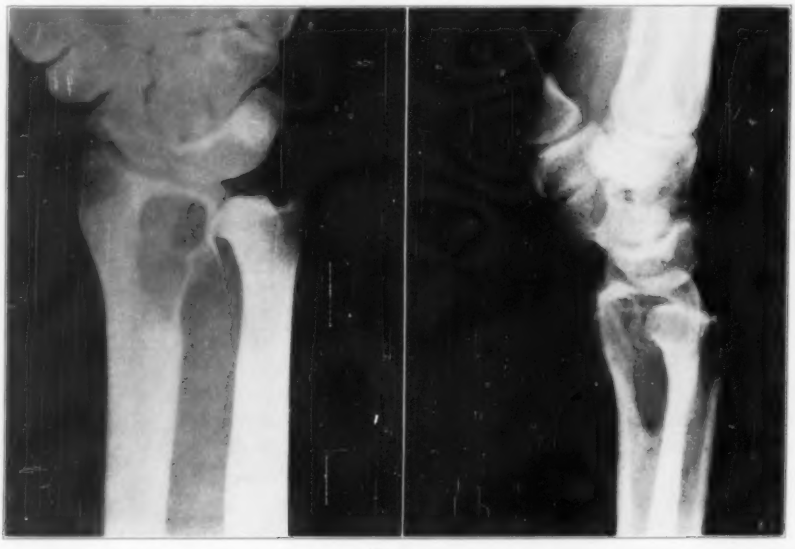

FIG. 1

Anteroposterior and lateral roentgenograms of the right wrist made September 21, 1949, showing the expansile lesion of the distal end of the radius. A congenital synostosis of the lunate and triquetrum is noted as an incidental finding.

erable multilobulated tumor by the time the patient consented to undergo further surgery. He was admitted to the Hospital for Joint Diseases on January 14, 1952. There were now bulbous soft-tissue swellings of both the extensor and the flexor surfaces of the joint, mainly on the ulnar side. Roentgenograms (Fig. 5) showed erosion of the fibular graft. The erosion did not extend beyond the junction of the graft with the shaft of the radius. Linear lattice-like calcifications were visible in the soft tissues. Motions of the wrist and function were fairly good. Dorsiflexion and palmar flexion were possible to an angle of 20 degrees supination to the thumb-up position and pronation to an angle of 160 degrees. There was a small range of

FIG. 2

June 13, 1950. The recurrence of the lesion is shown.

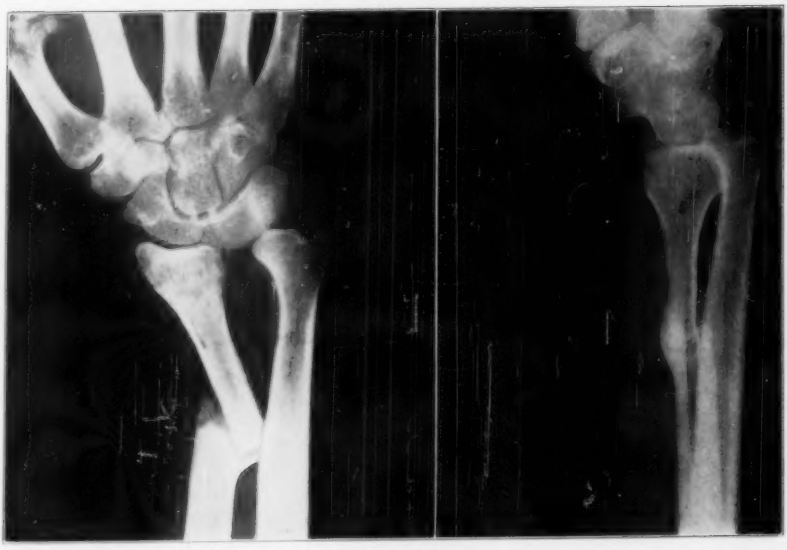

FIG. 3

March 2, 1951. The resected portion of the radius has been replaced by the fibular graft. Union of the graft has occurred with angulation at the site of the junction of the graft with the radius.

ulnar and radial flexion. The fingers could be flexed and extended completely, and strong grasping power of the hand existed.

In view of the second recurrence with pronounced extension of the tumor into the soft tissues and in view of the aggressive appearance of the tumor microscopically, as judged by Dr. Henry L. Jaffe, ablation of the affected limb above the elbow was advised. However, the patient steadfastly refused to consider ablation. The decision was therefore made to

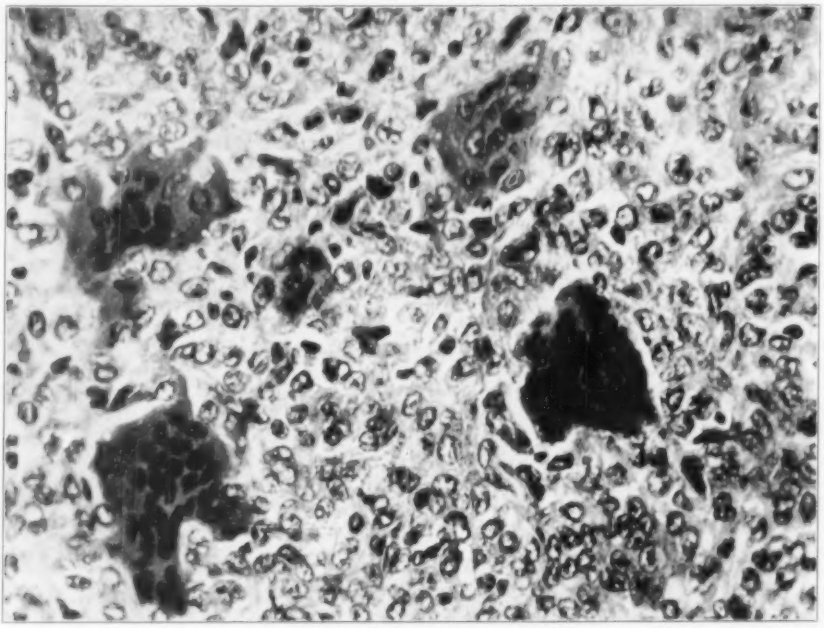

FIG. 4

Microscopic section, high-power field, of the tissue removed at the time of the second operation.

FIG. 5

Roentgenograms made January 3, 1952. There is erosion of the fibular graft due to recurrence of the tumor associated with soft-tissue swelling with linear calcifications.

repeat the resection and substitute an acrylic prosthesis for the distal end of the radius. The wrist could then be subjected to intensive radiotherapy without fear of interfering with bone healing. If another bone graft were to be implanted, this would have been a consideration. It was hoped that some function of the wrist might be preserved.

At surgery on February 5, 1952, although there was a pseudocapsule enclosing the tumor, the tissue was very friable and resection was difficult. A combined anterior and posterior approach was used. Tumor spill was unavoidable since the tumor tissue oozed like caseous material. The tumor was found to surround the extensor tendons of the wrist, extending through the interosseous membrane into the flexor compartment. The technical difficulties notwithstanding a fairly complete excision was accomplished as regards grossly visible tumor tissue. The distal three-fourths of an inch of the ulna was also removed to permit better application of the prosthesis and better support of the wrist. The stem of the prosthesis was then introduced into the medullary canal of the radius and the prosthesis tapped into place. The wounds were closed in the usual manner.

The prosthesis (Fig. 7) was made of acrylic with a long stem of stainless steel partially imbedded within it. The stem was actually an abbreviated, hollow, intramedullary pin seven millimeters in diameter. The size of the prosthesis was planned from the roentgenogram of the normal wrist, and the articular portion was shaped in a saucer-like fashion in order to support the entire proximal row of carpal bones.

Microscopic sections of the last specimen were similar to the previous two. A number of mitotic figures were evident in places.

The patient withstood the surgery well. There was a slight breaking down of the dorsal incision which healed after a few weeks. The wrist was immobilized in a bivalved plaster-of-Paris encasement to permit dressings and roentgen therapy after the wounds had healed. A total of 5,228 r were administered by means of a supervoltage machine (2,000,000 volts). Immobilization was discontinued after two months. At this time, there was a small range of motion at the wrist and a fair range at the fingers. Gradual improvement in the use of the wrist and hand followed. The patient was able to resume work as a postal clerk six months after the operation; subsequently, as an elevator operator, he constantly used the right hand.

At a follow-up examination in May 1953, fifteen months after the excision of the recurrent tumor and insertion of the prosthesis, the patient had good use of the right wrist and hand. Although marked stiffness of the wrist was present, it was very stable. A range of approximately 15 to 20 degrees of motion in each direction was possible at the wrist. Pronation of the forearm was practically complete, and supination, to 10 degrees better than the thumb-up position. The fingers showed no restriction of motion and the grasp was firm. There was no epitrochlear or axillary lymphadenopathy. The roentgenograms of the chest were

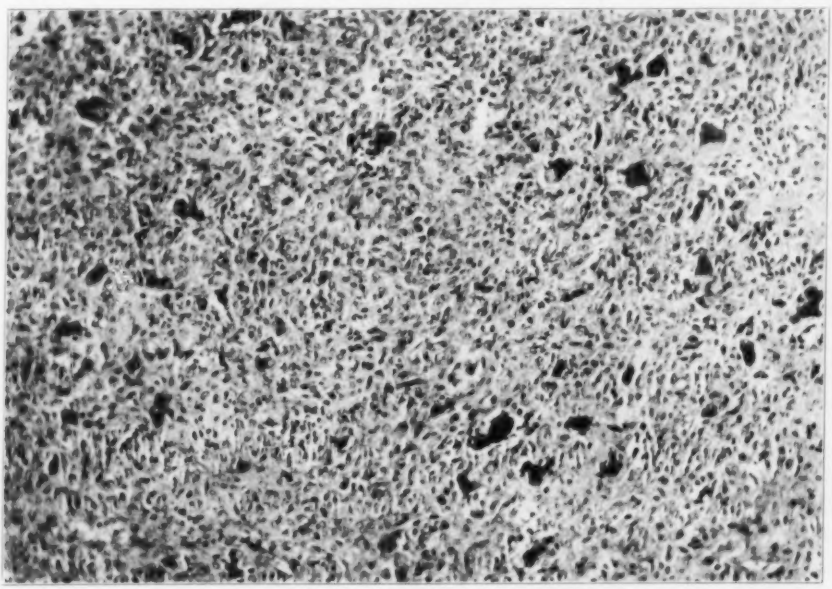

FIG. 6

Microscopic section, low-power field, of the tissue removed at the last operation.

negative for adventitious masses. There was no recurrence of tumor formation about the wrist. Roentgenograms (Fig. 8) showed the resected portion of the radius with the wrist being maintained in good functional position by the prosthesis. The distal end of the ulna and the juxtaposed carpal bones showed some irregularity. Small areas of calcification were present in the soft tissues about the wrist.

A short time later, the patient obtained work as a serviceman on new cars. The work was heavy and frequently required changing tires on the vehicles. In December 1953, twenty-one months after the last operation he experienced increasing discomfort in the right wrist associated with progressive disability and a clicking on motion. He recalled no sudden incident or sudden pain. He had to seek lighter work. When examined January 1954, the range of motion of the right wrist and hand were about the same. However, a click and false motion were observed along the radial side of the forearm just proximal to the wrist. Roentgenograms revealed a fracture of the prosthesis at this level. Function of the wrist and hand was still good and he did not experience significant pain on ordinary use. However he could not exert more than moderate force with the hand.

The patient was checked at intervals of six months since that time. For the past two years he has been employed as a shipping clerk. At the time of his last visit in January 1957, five years less one month from the time of the last operation, and more than seven years after the original curettage, the patient was alive and well. During the past three years, there has been no significant change in the function of the wrist or in its roentgenographic appearance (Fig. 9). Roentgenograms of the chest were negative for any metastases.

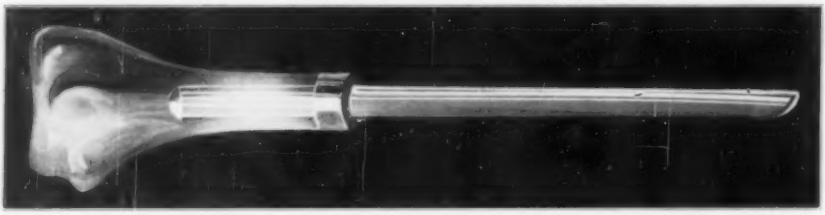

FIG. 7

Drawing of the acrylic prosthesis for the distal portion of the radius with the stainless-steel stem. The grooves for the tendons are exaggerated in the drawing and the embedded portion of the stem in the actual prosthesis had two notches.

COMMENT

This case demonstrated the aggressive tendencies of a true giant-cell tumor of bone. It showed, furthermore, that a secondary resection of the involved portion of bone may not be adequate to arrest the growth when extension into the surrounding tissues occurs. Simmons deduced from studying the material of the Bone Sarcoma Registry of the American College of Surgeons that primary resection as well as amputation was effective in producing a cure of giant-cell tumor of bone. A good functional result was obtained temporarily in this case by using the proximal portion of the patient's right fibula as a graft to replace the resected end of the radius. The successful implantation of similar grafts has been reported. The good result in this case was vitiated, of course, by the recurrence of the tumor.

The lack of metastases in spite of the gross contamination of the wounds with spillage of tumor during surgery is noteworthy. Cases have been reported in which after repeated procedures (as many as six curettages in one case) there were likewise no metastases[1, 12], lending support to the protagonists of the theory of the benign nature of this lesion. The roentgen therapy may have been a factor in preventing a recurrence thus far in this case. Nevertheless, it is too soon to predict the final outcome particularly because of the roentgen therapy. It has been intimated by Jaffe[7, 8] and stated by others[3, 4, 6, 9, 10] that the metastases from giant-cell tumors and malignant transformations now being reported with greater frequency may be the result of increasing use of roentgen therapy.

The implantation of a prosthesis for the distal portion of the radius helped maintain the general anatomical arrangement of the wrist during administration of intensive radiotherapy after the secondary resection of the tumor. This approach to the treatment of certain bone tumors of low-grade malignancy by wide bone resection, replacement by an

inert bone substitute, and intensive radiation may offer a satisfactory mode of management in selected cases.

At the time of the operation acrylic was felt to be a satisfactory material for the prosthesis. If such a prosthesis were to be used at the present time, Vitallium would be selected as more desirable. Also, two notches, not called for in the original design, were placed in the portion of the stainless-steel stem imbedded within the acrylic in order to effect a secure junction. The fact that the fracture of the prosthesis occurred at one of the notches would tend to indicate a weakness produced by the notches.

The case did demonstrate the feasibility of using an acrylic prosthesis for the distal end of the radius. The functional result was fairly good despite the scarring from two previous procedures and the results of heavy irradiation used. The case further demonstrated that such a prosthesis cannot be subjected to the continuous strain of heavy work. Fatigue fractures of prostheses are being noted more often especially in those made of plastic materials[2, 5].

SUMMARY

A case of an aggressive giant-cell tumor of the distal end of the right radius in a young adult male was presented. Two recurrences of the tumor followed, each within a year after surgery; the first, after curettage and implantation of bone chips from the ilium; the second, after resection of the distal portion of the radius and replacement by grafting the proximal portion of the patient's right fibula. A third operation was performed to remove the recurrent tumor and the eroded fibular graft, and to insert an acrylic pros-

FIG. 8

FIG. 9

Fig. 8: May 13, 1953. Fifteen months after the insertion of the prosthesis, a satisfactory position of the wrist and of the prosthesis is evident.

Fig. 9: Roentgenograms made January 9, 1957, almost five years after insertion of the prosthesis. The fracture of the metallic stem is noted as well some loss of position of the wrist. Soft-tissue calcifications are present mostly along the margins of the prosthesis.

thesis as a substitute for the distal fourth of the radius. This was an alternative to amputation to which the patient objected. Heavy irradiation was given shortly after the surgery. A good functional result was obtained with a small range of motion at the wrist. The patient was able to do heavy work; however, the prosthesis fractured after two years. Fairly good function continued, and despite the fracture of the prosthesis, the result has remained satisfactory to date without recurrence of the tumor.

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True Diastasis of the Sacro-Iliac Joints with Hypermobility

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Although much has been written about normal and abnormal motion of the sacro-iliac joints, we have been unable to find a recorded case in which non-traumatic diastasis of these joints is clearly shown on a roentgenogram or in which unquestionable pathological motion of this joint has been demonstrated at the time of operation. A patient with such a condition has been under treatment at the Mayo Clinic and we wish to present a summary of the case.

A white married woman, thirty-four years old, first came to the clinic on March 18, 1948, complaining of pain about both hips. She had had the pain for approximately five years. About eight years prior to admission, pain and stiffness, which she had attributed to rheumatism, had developed rather acutely in the lower part of her back. Her symptoms were severe enough to confine her to bed for one month. She recovered from this difficulty shortly after extraction of all of her teeth and remained asymptomatic until her present trouble began.

Five years prior to admission and shortly after the birth of her fifth child, the patient noted rather severe mid-back pain which soon spread to include the regions of both hips and extended into both lower extremities. The symptoms were rather vaguely described, but apparently diffuse aching in these regions was the primary problem. The symptoms, which varied from day to day, were continuous and were seemingly aggravated by inactivity and warm weather. The patient felt better when she was up and about and working. Back pain, present after recumbency, was sufficient to awaken her frequently from sleep. About three years before being seen at the clinic, she first noted some weakness in both legs, and a bilateral limp became apparent. At this time, she began to have a sensation of fullness in both lower extremities which felt, to her, as though inflated blood-pressure cuffs were about them. This sensation was increased by walking and relieved by rest. When arising in the morning, she felt as though her hips "were falling or breaking apart" and she had to "limber up" before assuming her daily activities. Pain in her back had diminished slightly in the last few months preceding admission.

Physical examination revealed a mildly obese white woman who apparently was not in acute distress. She weighed 143 pounds and was sixty-two inches tall. Her blood pressure measured 120 systolic and 80 diastolic. The physical findings were not remarkable except for a peculiar waddling gait, both hips being thrown forward as the patient walked. She had an increased lumbar lordosis with the suggestion of a lumbosacral shelf. The result of the Trendelenburg test was positive bilaterally, and the result of the straight-leg-raising test was negative bilaterally. The lower extremities were of equal length.

Neurological examination revealed, in addition, some mild apparent weakness of muscles about the pelvic girdle and an area of hypo-aesthesia along the lateral aspect of the right limb, felt to be due to irritation from the sacro-iliac joint. Deep tendon reflexes were active and equal.

All routine laboratory examinations gave essentially negative results. The erythrocyte-sedimentation rate was thirteen millimeters in one hour (Westergren method).

Roentgenographic examination of the pelvis and lumbar portion of the spinal column showed diastasis of both sacro-iliac joints with measurable superior subluxation of the surfaces of both iliac joints (Fig. 1). There was moderate reactive sclerosis along the joint margins, particularly on the iliac surfaces. Orthopaedic consultation was obtained and it was felt that the symptoms and findings represented bilateral sacro-iliac arthritis secondary to instability of the sacro-iliac joints. Fusion of these joints was advised and the advice was accepted.

On March 27, 1948, bilateral sacro-iliac fusion was performed according to the method described by Campbell. Following exposure of the sacro-iliac joints, a bone holder was clamped onto the posterior wing of the ilium on either side, and with very little force the iliac bones could be moved upward, downward and lateralward through an excursion of one centimeter, demonstrating the suspected marked instability. In the ligamentous region of the sacro-iliac joint on the left, a pocket containing semiliquefied necrotic material was entered. This material was evacuated and sent for histological study and culture, the cultures subsequently

* The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

were reported negative for tubercle bacilli or other pathogenic organisms. The sacro-iliac joints were then cleaned out as thoroughly as possible and filled with bone chips taken from the adjacent iliac crests.

Histopathological examination of the tissue removed at operation revealed focal and perivascular collections of lymphocytes and plasma cells, focal oedema, or mucoid alterations of ligamentous tissue with fibroblasts, and moderate arteriosclerosis. The cortex and marrow of the bones were not remarkable.

The patient's postoperative course was uneventful. She was kept in bed for a full ten weeks postoperatively, although she was dismissed from the hospital after the fourth week. She remained at home another seven weeks, getting up in a wheel chair and gradually increasing weight-bearing. When seen at the end of this period, she stated that she had had no falls, pain, or any of the particular preoperative symptoms. Gradual increased activity and ambulation were permitted.

The patient was seen again ten months postoperatively. At this time, she was feeling well and had only occasional discomfort in the sacro-iliac region. Although she walked with a slight lurch, roentgenographic examination showed good fusion of both sacro-iliac joints.

FIG. 1
Appearance of sacro-iliac joints before operation.

The patient was last seen at the clinic in August 1954, approximately six and one-half years after surgery. At that time, she denied having pain of any consequence in the lower part of the back or the hips, and she walked normally. The Trendelenburg sign was negative bilaterally. She did, however, complain of intermittent aching which was steadily becoming worse in the thoracic and upper lumbar portions of the spinal column. She also complained of considerable morning stiffness. Because of these symptoms and the findings of an elevated sedimentation rate (thirty-eight millimeters in one hour by the Westergren method) and decreased expansion of the thorax, the arthritis consultant who saw her felt that the history and physical findings were fairly typical of rheumatoid spondylitis. However, we were unable to detect any supportive evidence in the roentgenograms. Roentgenographic examination showed solid fusion of both sacro-iliac joints (Fig. 2).

A very recent report states that the patient is well in all respects.

COMMENTS

From earliest times there has been much controversy over the Hippocratic theory of disjunctio pelvica [1]. Seemingly thorough anatomical investigations by Sashin and by MacDonald and Hunt in recent years have supported the descriptions of the sacro-iliac joints given in well known texts of anatomy. They have confirmed the presence of true synovial diarthroidial joints composed of articulating cartilage together with an enveloping synovial membrane and fibrous capsule. Except in infancy, all sacro-iliac joints have been found to be extremely stable. Sliding and rotatory motions have been demonstrated

in very slight degree. With increasing age, progressive degeneration of the articular cartilage with secondary bony alterations has been shown to occur. To a lesser extent, concomitant changes in the synovial tissues and capsule also occur. MacDonald and Hunt found solid fusion of the sacro-iliac joints in eleven of forty-one cadavera of persons more than fifty years of age.

Abnormal motion in the sacro-iliac joints has been indicated as the cause of a galaxy of symptoms, including pain in the lower part of the back, pelvis, and lower extremities. These have been explained on the basis of irritation of portions of the lumbosacral plexus, and in particular, the lumbosacral trunk of the sciatic nerve which usually lies just anterior to the inferior margin of the sacro-iliac joint [5]. Great impetus to such thinking was given

FIG. 2

Appearance of sacro-iliac joints after fusion.

by the paper written by Goldthwait and Osgood in 1905, and frequent reference to their work by subsequent authors has been noted.

Attempts to show and measure objectively motion in the sacro-iliac joints have been made by several authors[2,11,13,14]. In none of the roentgenographic reproductions was there evidence of separation of these joints. The Chamberlain technique of roentgenographically measuring motion in the sacro-iliac joints was used by Anderson and Peterson in 144 cases. This technique is based on measurement of malalignment and separation of the symphysis pubis, assuming that changes in this joint are secondary to abnormal motion in the sacro-iliac joints. These investigators found that changes seen by this method correlated with essential clinical findings in 82.1 per cent of cases, thus qualifying the value of the technique. No special technique was used nor was one necessary to demonstrate abnormal motion in our patient. The preoperative roentgenogram (Fig. 1) was made with the patient in the supine position.

Two cases of congenital dislocation of the sacro-iliac joints [8,9] and many cases of posttraumatic dislocation of these joints have been recorded. Patients in whom diastasis of the sacro-iliac joints has been described and in whom no known trauma has been indicated have almost invariably been women [1,4,8,11,13]. The authors reporting these cases seem to have agreed in their belief that this may well be due to hormonal influence, in that symptoms which led to investigation of the condition usually occurred during pregnancy. The

hormone relaxin was first extracted from the corpus luteum of the sow and was used to demonstrate relaxation of the pelvic ligaments of guinea pigs [7]. A similar substance was subsequently found in pregnant women although the exact tissue responsible for its secretion has not been determined.

Prior to the onset of her disabling symptoms our patient had five pregnancies with little or no trouble, to our knowledge, during any of them. Since relaxin is present throughout gestation only, one would expect symptoms due to relaxation of the pelvic joints at least to arise during this period. Abramson, Roberts, and Wilson stated that "a waddling gait was frequently noted" and that a positive Trendelenburg sign was demonstrated in many of the pregnant women investigated for relaxation of the pelvic joints. These findings occurred during pregnancy and disappeared within a month after its termination. Most of the women, however, received treatment with a pelvic belt for support.

It is our theory that the changes in the sacro-iliac joints of our patient more likely represented an unusual but extremely disabling early change attributable to rheumatoid spondylitis. Subsequent follow-up examinations have indicated this disease to be present. Changes in the sacro-iliac joints are known to be found early in rheumatoid spondylitis. Usually, however, these changes consist of marginal sclerosis with later fusion. Recently, rheumatoid granulomatous nodules have been found to involve vertebral bodies and adjacent intervertebral discs with collapse of the bodies and destruction of the joint [3]. Whether this actually was the basis for destruction of the joints in our patient could not be determined from the tissue removed at the time of operation, but the pathological characteristics of the tissue are suggestive.

SUMMARY

A case is presented in which bilateral diastasis of the sacro-iliac joints and grossly abnormal motion could be demonstrated. Sacro-iliac fusion relieved the patient of her disabling symptoms. It is theorized that destruction of these joints was an unusual but extremely early finding in rheumatoid spondylitis and may have been caused by the presence of rheumatoid granulomatous nodules.

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Ganglioneuromata in Bone

Report of a Case

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Ganglioneuroma is a tumor composed of sympathetic ganglion cells and many sheathed nerve fibers. Stout [1] divided ganglioneuromata into three groups: (1) a fully differentiated group which does not metastasize and which includes a great majority of the tumors; (2) a partly differentiated group which occasionally gives rise to metastases; and (3) a small but complex group made up of both fully differentiated ganglioneuroma nodules and fully malignant sympatheticoblastomatous nodules, the majority of which metastasize. Many examples of metastasizing ganglioneuromata have been reported in the literature. Stout [2], writing for the Armed Forces Institute of Pathology, stated that the fully differentiated ganglioneuromata do not metastasize. These comprised approximately three-fourths of the ganglioneuromata reported in his monograph. In the remaining one-fourth there was incomplete differentiation. This group could be further divided into two different forms: in the first form metastases occurred in approximately 18 per cent, while in the other metastases occurred in 65 per cent. In every case the metastases were to the soft tissues. A review of the listings in the *Index Medicus* back to and including the year 1915 revealed no reports of ganglioneuromata in bone.

The patient, a white male, twenty-two years old, was seen originally in Maine in July 1955 by his local naval medical officer, complaining of an intermittent dull ache in the region of the right elbow of two years' duration. A roentgenogram of the right elbow was made, and a bone lesion was noted in the right ulna. The man was admitted to the United States Naval Hospital, Portsmouth, New Hampshire, where, on July 27, 1955, a biopsy of the lesion of the right ulna was performed. The specimen was submitted to the First Army Area Medical Laboratory in New York City, and the diagnosis of ganglioneuroma of the right ulna was established. The patient was transferred to the United States Naval Hospital, Chelsea, Massachusetts, for further study and treatment and to appear before a tumor board. Further history obtained on his present admission to the hospital failed to reveal any trauma, weight loss, or other pertinent data.

The patient's past history was negative for skin or bone diseases. No previous bone roentgenograms had been made.

The family history was negative for any type of tumor, skin disease, or bone disease.

The results of the physical examination were within normal limits except for a well healed surgical scar in the region of the proximal end of the right ulna. There was no swelling, discoloration, pain on pressure, or other abnormal findings referable to the right elbow. General examination failed to reveal any unusual skin pigmentation or other evidence of neurofibromatosis.

Results of indicated laboratory investigations were as follows:

Examination of the blood revealed a hemoglobin of 14.5 grams per 100 milliliters and a white-cell count of 7,200 with 62 per cent neutrophils, 34 per cent lymphocytes, and 4 per cent eosinophils. The serum calcium was 11.0 milligrams per 100 milliliters; the serum inorganic phosphorus was 4.2 milligrams per 100 milliliters; and the alkaline phosphatase was 2.0 Bodansky units.

Bleeding time was 1 minute and 55 seconds; coagulation time was 2 minutes and 30 seconds.

Sedimentation rate was 10 millimeters per hour (Cutler method).

Urinalysis was within normal limits.

Kahn test was negative.

Roentgenographic examination, which included a skeletal survey, revealed bone defects in the right humerus, right radius, and right ulna (Figs. 1-A and 1-B), the fourth lumbar vertebra (Fig. 2), and the left tibia (Fig. 3). It is interesting to note the different appearance of the lesions in the right ulna and left tibia. Chest and abdominal roentgenograms and intravenous and retrograde pyelograms were considered to be within normal limits.

A biopsy of the left tibia and a second biopsy of the right ulna were performed on August 25, 1955. The pathologist reported ganglioneuroma of the mature type. Figures 4-A to 4-D show representative sections of

FIG. 1-A

FIG. 1-B

FIG. 2

FIG. 3

Fig. 1-A: Oblique view of the right humerus shows a radiolucent lesion in the distal one-third which encroaches upon the cortex medially but is well demarcated and in some areas bounded by a sclerotic margin.

Fig. 1-B: Lateral view of the right radius and ulna before biopsy shows a multiloculated lesion below the sigmoid notch in the ulna which is well demarcated at the periphery and which contains radiolucent and sclerotic areas. The radial lesion is in the proximal one-third, is primarily radiolucent, and is not demarcated by sclerosis.

Fig. 2: A radiolucent, rounded lesion occupying the middle one-third of the posterior portion of the body of the fourth lumbar vertebra and surrounded by sclerosis is evident.

Fig. 3: A lobulated radiolucent medullary lesion of the mid-portion of the left tibia is shown. The cortices immediately adjacent are thinned and a thin zone of demarcation by sclerosis is seen.

FIG. 4-A

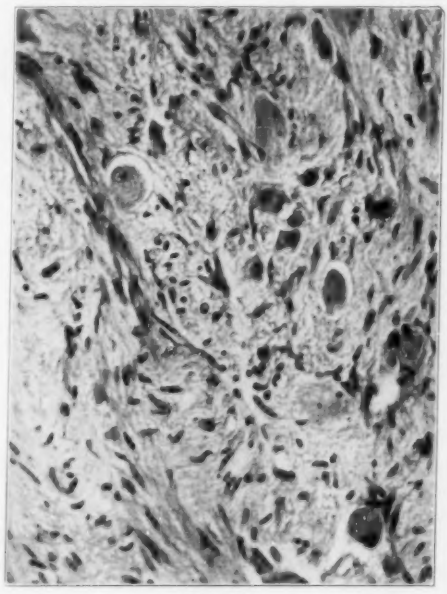

FIG. 4-B

Fig. 4-A: Low-power view (× 145) demonstrates one of numerous areas containing parallel and palisading fibers. Suggestions of herring-bone pattern are present. A few nerve cells are scattered throughout the lesion. Bone spicules do not seem to be part of the lesion (Courtesy of the Armed Forces Institute of Pathology).

Fig. 4-B: Ganglion cells of large and small size are seen (× 310). Numerous axons in cross section are evident below the large cell on the left. (Courtesy of the Armed Forces Institute of Pathology).

the tumor from the right ulna. The patient (May 24, 1957) is alive and apparently well except for an occasional ache in his arm noted on lifting heavy objects.

Microscopic slides from the first biopsy sections were reviewed by the Armed Forces Institute of Pathology in Washington, D. C., with concurrence in the diagnosis of ganglioneuroma of the right ulna and the left tibia. Dr. Lent C. Johnson's report follows:

"Material received from both biopsies of the right ulna and the material from the left tibia all have presented essentially the same appearance. Substantial portions of the tumor are made up of elongated fibroblastic nuclei embedded in the background of delicate eosinophilic fibrous material which grows in broad, very much elongated fascicles that sweep, swirl, and interlock with each other. In such areas the general pattern is essentially similar to that seen in a neurofibroma. No Verocay bodies are noted.

"The second and perhaps the most substantial component consists of long sweeping fascicles of Schwann cells organized into very tiny delicate tubules and packed together into bundles of varying sizes. Cut longitudinally, these tubules extend as far as they can be traced in any direction. Cut transversely, the tubules present the pattern of a very delicate honeycomb. In all respects these portions of the neoplasm appear to be made up of Schwann cells that form tubules with little or no myelin in them and resemble the swirling, sweeping patterns that are seen in an amputation neuroma.

"Bodian stains demonstrate a rich abundance of axonal fibers in all of the delicate tubules and a less rich scattering of unmyelinated fibrils in the portions that resemble neurofibroma.

"Scattered everywhere through the lesion are numerous very large cells characterized by a large, perfectly round, generally clear nucleus with a single very prominent centrally placed nucleolus and by

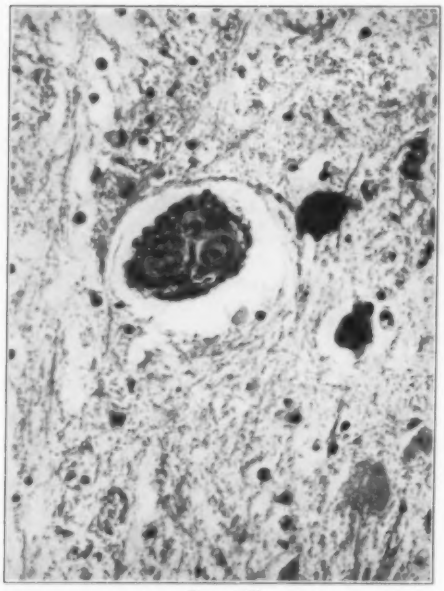

FIG. 4-C

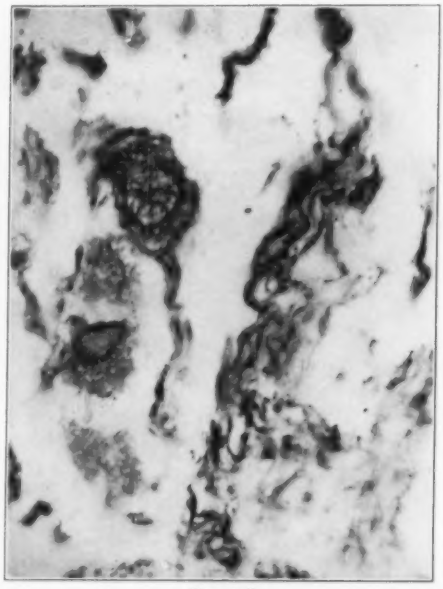

FIG. 4-D

Fig. 4-C: Detail of ganglion cell showing Nissl substance and lacuna (× 305) (Courtesy of the Armed Forces Institute of Pathology).

Fig. 4-D: High-power view shows argyrophile staining of axon and large cell with numerous neurofibrils in adjacent fiber bundles (Bodian stain, × 730) (Courtesy of the Armed Forces Institute of Pathology).

an abundant cytoplasm which is several times the volume of the nucleus. The cytoplasm is finely granular and at times vacuolated. Nissl's stains demonstrate an abundance of very fine Nissl-like chromidial substance throughout the cytoplasm of many cells. In fortunate cuts axonal fibers (which take the Bodian stain) can be demonstrated to arise from these large ganglion cells. In some instances delicate dendritic processes can be seen in Bodian stains about a part of the circumference of the cells. Satellite cells are exceedingly rare; the majority of the ganglion cells are not associated with satellite cells.

"Nowhere are there to be found any undifferentiated cells or any patterns indicating mixed or malignant types of ganglioneuroma. The tumors appear entirely benign and completely quiescent. There is no mitotic activity or other evidence of proliferation.

"Since the lesions are composed of fibrous elements resembling a neurofibroma, of neurolemmal cell elements resembling an amputation neuroma, and of neuronal ganglion cells with chromidial Nissl substance, the diagnosis is multiple ganglioneuromata of bone, intramedullary."

This case report, we believe, represents the first report of ganglioneuromata in bone. The origin of the tumors is conjectural. The possibilities as to origin are: (1) the tumors are primary in bone and of multicentric origin; (2) a primary ganglioneuroma of the sympathetic nervous chain metastasized to bone; and (3) a primary neuroblastoma metastasized to bone with maturation of the peripheral metastases.

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Intramedullary Fixation of Fractures of the Femur in a Case of Osteopetrosis

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The fragility of the dense sclerotic bones characteristic of Albers-Schönberg disease (osteopetrosis, marble bones, or osteosclerosis fragilis) leads to an increased incidence of fractures. The fractures involve most frequently the inferior border of the neck of the femur, the upper third of the shaft of the femur, and the upper third of the tibia[1]. Healing is variable, and orthopaedic management is complicated by the underlying abnormality of the cellular metabolism of the bones. The disease is rare, less than 200 cases having been reported in the literature.

This report is the second concerning a patient who first came under medical observation at the age of three and one-half months and who was studied extensively at that time and at intervals since. It is presented in order to demonstrate the feasibility of intramedullary fixation of the femoral fractures prone to occur in this condition and to call attention to the unusual technical problems imposed by the hard but brittle bones characteristic of this disease. No previous account of the use of intramedullary fixation for fractures in patients with osteopetrosis was found in a search of the literature of the last ten years. Kleinberg, treating a subtrochanteric fracture in a patient with osteopetrosis, was unable to drive the blade of a blade plate into the femoral neck and had to use the plate segment alone. This he fixed to the shaft of the femur with screws. He commented on the hardness of the bone, saying "An electric drill was used to create the channels for the screws; even the drill penetrated with some difficulty."

The present patient first came to medical attention at the age of three and one-half months because of listlessness, weakness, and enlargement of the head. She was thoroughly examined by the Departments of Pediatrics and Radiology of the St. Louis University School of Medicine, where at intervals she was seen over the next ten years. Kneal and Sante wrote an excellent review of osteopetrosis and of this case, to which the reader is referred for detail concerning the findings summarized here. At the time of the original investigation, roentgenographic examination revealed an increased density of the cortices of some of the long bones, two centers of ossification in the wrist, and an enlarged skull which was not distinctive roentgenographically. Bone biopsy was done at the lower portion of the right femur, and a pathological diagnosis of osteoperiostitis was made from the specimen. The authors pointed out that the roentgenographic findings were inconclusive and that at this early stage of development "recognition of the disease was not possible from even the biopsy specimen."

Two months after biopsy, at the age of five and one-half months, the child sustained a spontaneous fracture just above the biopsy site in the mid-portion of the shaft of the right femur. "Within five weeks thereafter roentgen examination revealed complete union with an enormous amount of callus." Laboratory findings at this time revealed hypochromic anaemia, blood calcium of 12.4 milligrams per 100 cubic centimeters, and blood phosphorous of four milligrams per 100 cubic centimeters.

Nine months later the child was re-admitted for further medical study, and Kneal and Sante reported "by this time the bone lesions on roentgen examination were sufficiently advanced to suggest the true nature of the disease, and a diagnosis of 'osteosclerosis, probably due to Albers-Schönberg disease,' was made." The previously described biopsy specimen was reviewed and a further note was made that no fluoride crystals were seen in the sections. The authors commented on this because the child had resided in a small community near El Paso, Texas, which coincidentally had a high fluorine content in the drinking water. Poisoning by this material has been suspected as an etiological factor in the disease.

The child was then followed at intervals over the ensuing years, and continuing roentgenographic study showed the typical appearance of marble bones. Dense sclerotic zones had appeared along the diaphyseal sides of the epiphyseal lines; these gradually extended to involve the entire shaft of each femur. Dark longitudinal lines were noted within the calcifying bone and were thought to represent columns of uncalcified cartilaginous cells. The bones assumed a structureless chalky appearance. A club-shaped ap-

pearance of the ends of the long bones developed which was explained on the basis of widening of the ends of the long bones by the longitudinal striations.

At the age of eight, deafness was reported; this became slowly progressive. At this age, it was noted also that the child was several inches shorter than her younger sister; otherwise she enjoyed good health. At about this time, a second fracture of the shaft of the right femur occurred, unpreceded by any trauma sufficient to direct attention to it. Function was not suspended, and the child continued to walk throughout the period of repair. This was an incomplete fracture of the upper one-third of the shaft, and Kneal and Sante reported that "Only very slight periosteal bone occurred over the first seven months, and the line of fracture was not completely filled in with new bone for more than a year." The child had also at unknown times previously sustained bilateral infractions of the femoral neck and these showed "little evidence of repair over an extended period." Eventually these infractions healed but left the child with marked coxa vara, bilaterally.

FIG. 1

Roentgenogram of the patient at age eight and one-half. Note the bilateral coxa vara, the increased density of the bones characteristic of osteopetrosis, and the fracture of the upper one-third of the shaft of the right femur.

At eight and one-half years of age the patient was first seen in our office complaining of low-back pain of one month's duration. The pertinent findings on physical examination were bilateral coxa vara, an increase in the lumbar lordotic curve, and limitation of abduction and internal rotation of both hips. Roentgenograms of the lumbar spine and pelvis revealed increased density of the long bones and the vertebrae, an incomplete fracture of the upper third of the right femur, and pronounced bilateral coxa vara (Fig. 1). No specific treatment was undertaken and the patient's complaints subsided within a short period of time. The roentgenographic findings were considered characteristic of osteopetrosis. It was noted from the roentgenogram made at this time (Fig. 1) that the osteosclerotic process mainly involved the cortices of the femora; later roentgenograms showed involvement of both spongy and cortical bone and obliteration of the medullary canal.

The patient was next seen at the age of eleven and one-half years because she had hurt her right hip

in a simple fall while running. Roentgenograms revealed a transverse fracture of the upper portion of the right femur at exactly the place of the incomplete fracture of the shaft of the femur seen in Figure 1. An increase in the dense sclerosis of the bones was observed. She was hospitalized and extensive laboratory studies at this time revealed moderate hypochromic anaemia.

On the second hospital day, under general anaesthesia, an open reduction of the subtrochanteric fracture of the right femur was carried out through a lateral incision made at the junction of the middle and upper thirds of the right thigh. The fracture site was exposed, and a transverse fracture with the bone ends clearly and sharply demarcated was seen. The bone ends presented a solid-white, grossly amorphous appearance. The medullary canal had been completely obliterated by hard bone and was indistinguishable from the cortex. Attention was first directed to the proximal fragment, and the area which normally would have been the medullary canal was drilled with an electrician's drill. Because of the brittleness of the bone, extreme care was exercised in order not to shatter the femoral shaft. The hard, dense quality of the bone made

FIG. 2

FIG. 3

Fig. 2: Anteroposterior roentgenogram of the left femur made two months after original fracture. This is at the time full weight-bearing was begun. Four months later a re-fracture occurred associated with fracture of the nail.

Fig. 3: Lateral roentgenogram of the left femur made two months after original fracture. This is at the time full weight-bearing was begun. Four months later a re-fracture occurred associated with fracture of the nail.

drilling most difficult. In similar fashion and with the same caution, the distal fragment was then drilled. The preparatory channels thus made were then gently and carefully cut with a broach. A regular large size (eleven millimeters by nine millimeters) Hansen-Street nail was selected, examined, and inserted retrograde into the proximal fragment. After careful reduction of the fracture, the nail was then driven down across the fracture site into the distal fragment. The long diameter of the nail was placed in the three-quarter plane of the shaft of the femur. Examination at the operating table revealed anatomical re-alignment of the fragments and stable fixation. Postoperative roentgenograms confirmed these findings and on clinical examination the fracture exhibited unusual stability. The postoperative course was uneventful and carefully repeated roentgenograms over the next ten weeks showed gradual bone consolidation at the fracture site. On the forty-second postoperative day the patient was allowed twenty pounds of weight-bearing. Full weight-bearing was permitted eight weeks after operation. A follow-up roentgenogram made in December 1951, somewhat less than six months after operation, revealed complete bone union of the fracture and the patient was allowed unlimited freedom of activity.

When she was thirteen, the patient was again hospitalized, for a fracture of the left femur sustained when she was knocked down on the street by a boy who jumped from the curbing and struck the patient with his knee on her left side, presumably in the area of the greater trochanter. Roentgenograms made at this time showed a transverse fracture three and one-half inches below the upper end of the femur. Once again, under general anaesthesia, an open reduction was done, and the fracture site was exposed. The ends of the proximal and distal fragments at the fracture site presented a solid-white, grossly amorphous appearance. There was no medullary canal. A channel was fashioned in the area in which the medullary canal should have been by means of a long electrician's drill. Although the entire femoral shaft consisted of osteosclerotic bone, the central portion was less dense than the cortices. The channel was widened with a broach

FIG. 4

FIG. 5

Fig. 4: Roentgenogram showing re-fracture and broken intramedullary nail, six months after insertion of the nail.

Fig. 5: Roentgenogram made five months after operation for the re-fracture of the left femur. Note bone union and globoid overgrowth of new bone.

and, as in the previously described operation, extreme care was taken not to fracture the shaft of the femur. A regular-size Hansen-Street nail was selected, and the usual examination at the operating table revealed no evidence of any defect. This nail was inserted into the femur, and anatomical re-alignment and stable fixation was accomplished. The immediate postoperative period was uncomplicated and forty-two days after operation the patient was allowed up on crutches with twenty pounds of weight-bearing. In April, two months after operation, full weight-bearing was allowed, bone union having progressed satisfactorily (Figs. 2 and 3).

In August 1953, some four months after full weight-bearing had been allowed, the patient again injured her left hip. On this occasion she had flexed the left hip with great force, using all her strength in order to take a long, high step. Severe pain developed in her thigh and about the knee. On her own decision, she returned to the use of her crutches for two weeks. Symptoms persisted, however, and at the end of August 1953 the patient returned for investigation. Roentgenograms revealed a re-fracture of the previously described

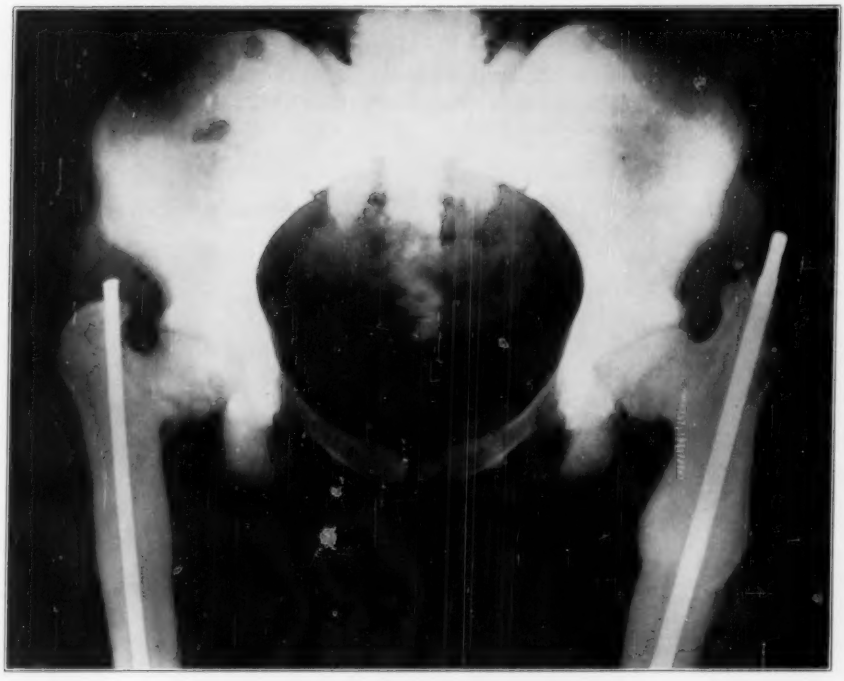

FIG. 6

Roentgenogram made one year after last operation showing both fractures completely healed.

subtrochanteric fracture of the left femur with an associated fracture of the Hansen-Street nail at the fracture site (Fig. 4).

Once again under general anaesthesia an open reduction of the subtrochanteric fracture of the femur was done. At this operation the approach to the fracture site was complicated by the fibrosis caused by the previous operation four months earlier and bleeding was more marked. The fracture site was surrounded by callus and soft new bone. The intramedullary nail, completely broken at the fracture site, was removed easily in its two sections. A new regular-size Hansen-Street nail was then selected, examined, and inserted into the proximal portion of the shaft of the femur and driven across the fracture site. Anatomical re-alignment and stable fixation were obtained. Bone chips from the area of new-bone formation were laid down about the fracture site and holes were carefully drilled in several places about the fracture site. A specimen from the area of the fracture was taken and submitted to the laboratory for microscopic study. This was later reported upon as follows: "Bone sections show normal trabeculation with no evidence of abnormal osteoblastic activity. There are focal areas of osteoclasis and focal regions of moderate fibrous hyperplasia. *No marrow* elements are seen. The trabeculations are relatively thick. The sections show no evidence of specific type inflammation or neoplasia."

The patient's postoperative period was uncomplicated and forty-two days after operation she was allowed up on crutches with twenty pounds of weight-bearing. Careful roentgenographic studies were done at intervals and showed gradual progression to bone union which became complete in March 1954, at which time, five months after operation, full weight-bearing was allowed. No further difficulty was encountered and the patient was doing well when last heard from two and one-half years later.

Figure 6 is a roentgenogram of the pelvis and femora made in November 1954, showing the fractured femora to be completely healed and each containing an intramedullary rod. The increased density of ilia and femoral shafts characteristic of osteopetrosis is apparent.

DISCUSSION

The diagnosis of osteopetrosis depends upon characteristic roentgenographic findings. The child with this disease as he grows is subject to a continuing series of minor infractions and major fractures usually caused by relatively inconsequent trauma that,

because of the brittleness of the osteosclerotic bones, results in serious damage, whereas the same trauma in a normal individual would not do so.

Healing of fractures in these cases is sometimes delayed. The use of intramedullary fixation to expedite bone union in suitable locations and under appropriate conditions appears to be advantageous.

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Femoral-Artery Reconstruction in a Patient with a Compound Fracture of the Femur

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Ligation of the major artery in an extremity results in gangrene of the limb in a high percentage of cases. Smith, Odom, De Bakey and Simeone, reporting on World War II casualties, recorded gangrene in 40 to 57 per cent of the extremities in which a major artery had been divided. In most of the patients, the injured artery was treated by ligation; in a limited number of the patients, various types of reconstruction were attempted, but without material change in the results.

During the Korean War it was the general policy in the American forces to attempt primary arterial repair in all casualties who reached a hospital that was equipped to render such treatment. This resulted in the salvage of many limbs. The amputation rate in the patients who survived their injuries varied from 9 to 20 per cent in the cases reported by Hughes, Jahnke and Seeley, and Jahnke and Howard. Spencer and Grewe reported similar results: an amputation rate of 21 per cent following the repair of the femoral artery and a considerably higher amputation rate (38 per cent) after repair of the popliteal artery.

As a rule, civilian injuries are not as destructive as those seen in battle casualties. The results of primary arterial repair should therefore be better, if the patient has the good fortune to reach a hospital within a few hours following injury. The technique of arterial repair is not difficult and should be within the capabilities of all general and orthopaedic surgeons. Some experience in the repair of animal vessels will enable a surgeon to undertake the repair of a divided artery with confidence in his ability to restore the circulation of the extremity.

A nine-year-old boy fell from a fourth-floor window and was impaled on an iron picket fence. His only serious injury was to the right thigh. This was caused by one of the spikes of the fence which perforated the thigh in its mid-portion, passing from the lateral to the medial surface.

A physician, who was driving by at the time of the accident, helped to remove the child from the fence and immediately transported him to St. Luke's Hospital. On arrival the patient was pale but not in shock and active bleeding had stopped. After plasma infusion was begun, the boy was transferred to the operating room for definitive treatment.

Under anaesthesia, careful examination of the wound revealed extensive soft-tissue damage, fracture of

FIG. 1

Large wound on medial aspect of patient's right thigh, where iron picket emerged.

FIG. 2

FIG. 3

Fig. 2: Roentgenogram showing fracture and extensive soft-tissue damage.

Fig. 3: Appearance of limb two months after injury. The wounds had healed and the pedal pulses were palpable.

FIG. 4

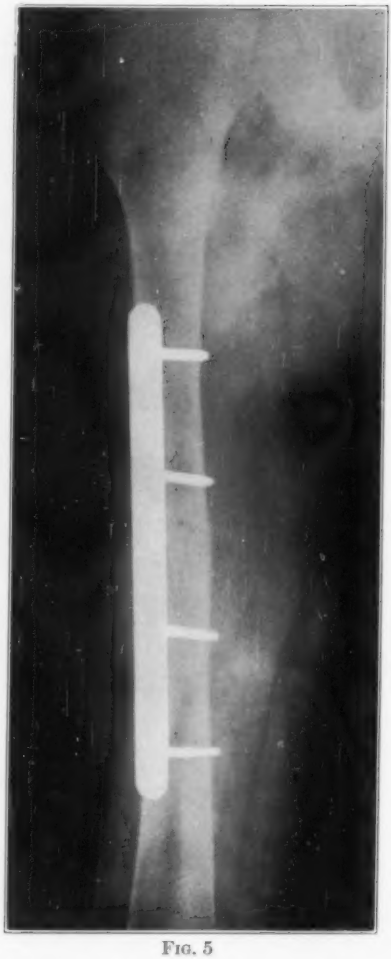

FIG. 5

Fig. 4: Arteriogram four months after injury. There was little evidence of new-bone formation.
Fig. 5: Roentgenogram made thirteen months after surgery showed solid union of the femur.

the mid-shaft of the femur, and complete division of the femoral artery and vein. The sciatic nerve appeared to be intact. Figure 1 shows the large wound on the medial side of the thigh. Roentgenographic examination demonstrated the fracture and muscle defect (Fig. 2). Repair of the artery and immobilization of the fractured femur with a metal plate was decided upon.

The wound was cleansed by irrigation with normal saline solution. Muscle and fascia which did not appear viable were excised. After reduction of the fracture, an end-to-end suture of the artery was attempted but could not be completed because of tension on the suture line, even with flexion of hip and knee. Since a graft was necessary to bridge the arterial defect, a segment of the adjacent femoral vein, about two inches in length, was excised and used as a graft.

The anastomosis was accomplished as follows: The divided femoral artery was occluded by a rubber-covered bull-dog clamp and the loose connective tissue dissected away from the ends of the vessel to facilitate placing of the sutures. The clot in each end of the artery was removed (milked out) and the vein sutured into place by means of everting mattress sutures of 00000 silk on an atraumatic needle. Several interrupted sutures were then used to close small persistent defects in the suture lines. It is important to use a graft of the proper length to bridge the arterial defect, for an anastomosis which results in tension on the suture line will almost certainly disrupt, while a redundant graft results in angulation and encourages thrombosis.

Upon completion of the anastomosis and removal of the occluding arterial clamp, a good flow of blood

FIG. 6

Appearance of thigh thirteen months after injury.

into the distal artery was apparent. A bone plate applied to the lateral surface of the femur held the bone ends in satisfactory alignment. Internal fixation was indicated to give support to the sutured artery and to prevent the possibility of further damage to the vessels from an unstable fragment. The divided muscles were loosely approximated with sutures and the skin defect partially closed. Dressings were applied and the extremity was immobilized by a double hip spica. Total fluid replacement was 1,500 milliliters of whole blood and 500 milliliters of plasma. The lapse of time between injury and restoration of blood flow was approximately four hours.

The boy's immediate postoperative course was uncomplicated. The foot remained warm and there was good motion of the toes and ankle. Roentgenographic examination showed bone alignment to be satisfactory. The wound healed without infection, being covered with epithelium in one month. There was, however, little evidence roentgenographically of bone repair.

Four months after injury an arteriogram showed the venous graft to be functioning well (Fig. 4). While larger than the artery, the vein did not appear abnormally dilated. Although aneurysms and thrombosis have been reported following the use of vein, artery, and synthetic grafts, we believe that this repair will stand up. The vein is protected by muscle and in time should acquire the strength of an artery, thereby decreasing the possibility of aneurysm formation. Thrombosis is unlikely because of the good blood flow in this young boy with normal arteries.

Six months following injury, because of failure of bone union, the fracture site was replated and grafted with autogenous iliac strips. Immobilization was reinforced by a plaster hip spica. Development of bone union was slow. It was thirteen months following injury before there was roentgenographic evidence of union and the cast could be removed (Fig. 5). There was marked limitation of knee motion six weeks following removal of the cast. The boy is ambulatory with crutches and it is expected that his knee motion will increase with use. The appearance of the limb thirteen months after injury is shown in Figure 6.

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Paleopathological Evidence Suggesting Pre-Columbian Tuberculosis of the Spine

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In February 1957, a human spine was discovered in Indian burial-ground excavations along the Cumberland River near Clarksville, Tennessee. It was a well preserved specimen of the spine showing evidence of healed tuberculosis of the thoracolumbar region apparently in an adult female living in pre-Columbian times.

The culture being investigated was that of the Middle Mississippi era. The Indians had migrated from the region which is now Texas and had lived in western Tennessee between 1200 A.D. and 1400 A.D.[2] They were the pre-Muskogean people who became the Creek, Chicasaw, and Choctaw tribes.

FIG. 1

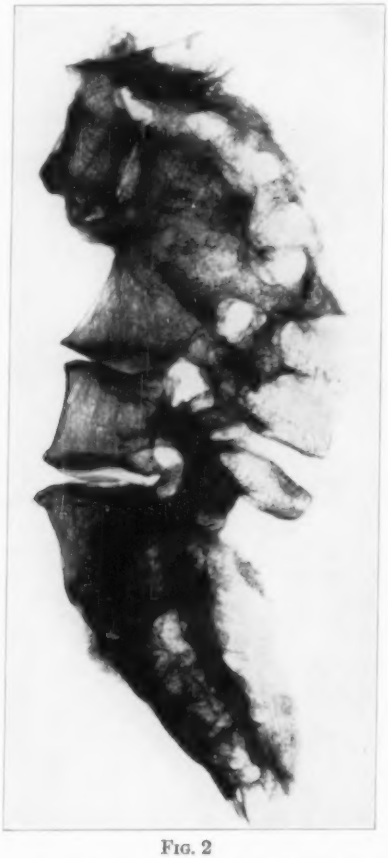

FIG. 2

Fig. 1: Side view (right) of the specimen showing fusion of the vertebrae, tenth thoracic through the fourth lumbar, and patency of the spinal canal.

Fig. 2: Lateral roentgenogram of specimen shows normal fifth lumbar vertebra and sacrum. Destruction of the intervertebral discs, collapse of the bodies, and fusion are demonstrated.

The Indians of the Middle Mississippi culture were a pastoral group and lived in small villages. Their diet consisted of maize, river mussels, and small and large game, including the plains buffalo. Early white settlers in western Tennessee described immense numbers of bison and other large wild game [4]. Burial grounds were located near rivers and their dead were placed in stone-box graves made by placing large slabs of limestone on all sides. Frequently with the body were sea and river shells, shell and stone ornaments, shell-tempered pottery, and arrowheads. Possession of sea shells suggests river trade with the southern coast.

The belief that the white man brought tuberculosis to America is being disputed by contrary evidence. Ritchie has reported pre-Columbian tuberculosis in kyphotic spines from three different cultures in New York. Explorations of Iroquoian Indian sites have revealed effigy pottery pipes illustrating hunchbacked individuals with pigeon-breast deformity and characteristic facies. From Tennessee, Arkansas, Missouri, and southeastern United States have come clay figurines and effigy water bottles of the Middle Mississippi culture that are also faithful representations of people afflicted with Pott's disease. The finding of tuberculous bone specimens has not been reported previously from the Middle Mississippi culture [5].

The question of origin and reservoir of tuberculosis in America has not yet been answered. This disease in man can be transmitted to animals (bovine) or contracted from them. Tuberculosis has been found in buffalo, elk, moose, and deer [1]. Following infection, buffalo become especially tolerant to the disease and most of them live to old age. In controlled infected herds it has been shown that the disease did not interfere with growth and natural increase in numbers.

This specimen, the skull and spine of which have been accepted for inclusion in the National Collections of the Smithsonian Institution, consists of a kyphotic thoracolumbar spine made up of seven vertebrae, the tenth thoracic through the fourth lumbar vertebra. Except for the most proximal one, all the intervening intervertebral discs have been destroyed. The vertebral bodies have collapsed and fusion has taken place. The intervertebral facet joints and neural arches are similarly affected. Throughout the kyphotic curve the spinal canal is patent and undistorted. The pathological changes are characteristic of spinal tuberculosis [5] (Figs. 1 and 2).

DISCUSSION

The existence of tuberculosis in prehistoric humans has been substantiated by the finding of evidence of bone tuberculosis in specimens of the spine. Supportive evidence is the associated discovery of effigy pottery and figurines depicting this condition. The existence of primary lung infection in these people can be concluded since bone involvement is secondary. A theory to be considered is that the bone disease may be of animal origin from tuberculous buffalo.

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Application of Punched Card Indexing Systems to Orthopaedic Surgery

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Classification of case record material is a fundamental requirement in the quantitative study of any disease or condition, yet there is probably no perfect method by which this may be accomplished. The purpose of this paper is to point out problems encountered in attempting to classify clinical data for the Department of Orthopaedic Surgery of The Johns Hopkins Hospital as well as to demonstrate what is presently thought to be a satisfactory classification method in three circumstances:

1. A needle sorting system of small numbers of cases perhaps up to 2,000 per year where little or no trained personnel for coding and sorting is available;
2. A machine sorting system for larger numbers of cases where a moderate budget is available;
3. A machine sorting system for very large numbers of cases where a full time statistical staff is employed.

A Small Index System

An example of a small-group classification system is one developed by the author for indexing cases of more than routine interest from the Department of Orthopaedic Surgery. Its purpose is to make readily available case histories and roentgenograms for teaching and for follow-up studies. It is designed for indexing on a three and one-half by seven and one-half inch McBee Keysort card which can be operated easily by one individual for indexing in a single year usually less than 2,000 cases. No attempt is made to classify such cases as sore feet and lame backs.

For a case to rate indexing it must be, in the coder's opinion, either one of some special interest, a case admitted to the hospital, or an operative case. All of the operative cases are indexed. Admittedly such a system may omit items of future interest, and there are different views of what is interesting. However, this slight exclusiveness makes the system much more simple to operate and has made it possible to classify the most useful clinical material with a minimum of effort. It far surpasses the memory of any individual; yet it is so inexpensive and simple anyone can use it in his own practice by carrying a few cards in his pocket, and, once a month or so, notching them and dropping them into a drawer. The entire notching process requires less than a minute per card, and the cards need be kept in no special order. The cost of each card is approximately one cent, and the sorting and punching equipment costs less than fifteen dollars.

The needle-sorting type of index card is a card with a series of holes punched around its edges. These holes match so that when the cards are aligned, an ice-pick type of needle can be passed through a given hole in all of the cards. By simply making the hole into a notch by means of a special punch, the notched card will drop from a group of cards suspended by the needle at that given hole (Fig. 1).

Looking at Figure 2, one can see, opposite the top holes of the card, the names of various anatomical parts printed on the card. (Do not be confused by the 7–4–2–1 number groups in this area, because they are not used in this part of the card.) Notice that the top seventeenth hole on the right represents the thigh. Simply by passing the needle through this hole all the cards notched at this hole will fall and these will be the cases involving the thigh. This is what is being done in Figure 1. Now note again in Figure 2 that the bottom margin of the card contains a series of diagnoses and operative procedures, each group opposite a hole. By passing the needle through *the dropped cards* (the cards already sorted for thigh) at the hole marked "simple fracture" all of the simple fractures of the femur (thigh) are separated from the file. It is remarkably simple and so rapid that a thousand cards can be sorted in a minute by an experienced sorter.

Figure 2 is an illustration of the most recent master card in use in the Orthopaedic Surgery Department. It has five main parts (Figure 2, *A*, *B*, *C*, *D*, and *E*) which correspond to the five most important facts which are necessary to look up a case history. These are: name (*A*), anatomical part (*B*), year of entry (*C*), etiology or disease process (*D*) and operation (*E*). The fact that only one card is used for collecting this data is one of the prime advantages of the system and is what makes it a true five-way cross index. Many other interesting facts could have been punched into the card such as age, sex, race, result, doctor, and history number, but these categories were seldom used to identify a case and were therefore rarely sorted. It is much less trouble to *avoid punching* this material into the card than it is to get it from the writing on the cards *after* they are sorted for a particular study. It is, however, important that these and other pertinent basic facts be written or sketched on the cards so that it is possible to get an idea of the exact nature of the case or why the case is interesting without having to check back to the history or roentgenograms. In this way the

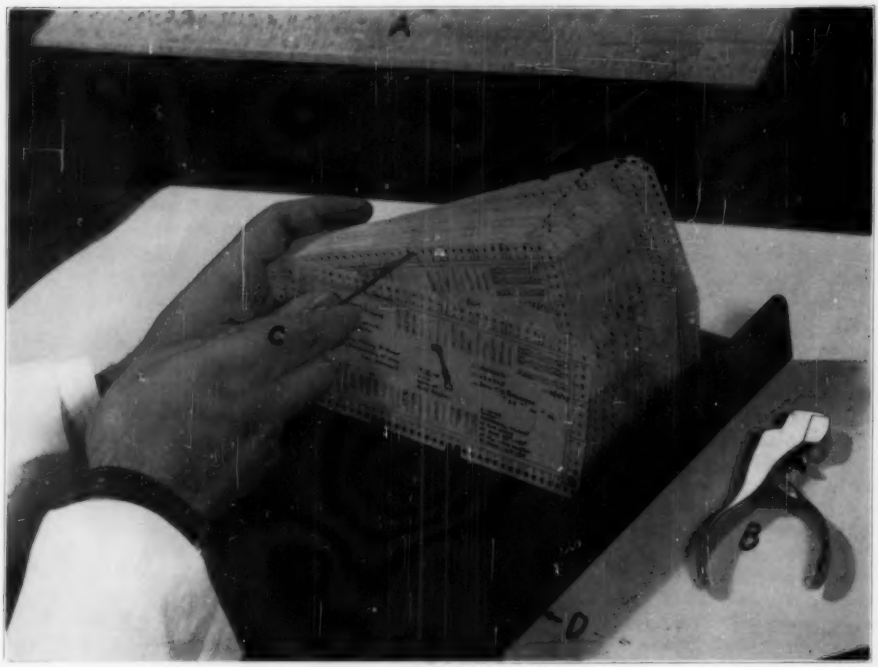

FIG. 1

This illustrates the needle-sorting mechanism for separation of the cases having conditions involving the "thigh." The needle has been passed through the top seventeenth hole from the right of a group of cards (which represents "thigh"). The cards which fall from the needle have previously had this hole punched out as illustrated in Fig. 2. The fallen cards will thus be the cases involving the thigh and they can be separated into the etiologic categories such as fractures, tumors, tuberculosis.

In the background is the file drawer (A) in which the cards are stored. This drawer contains all the indexed cases from 1956 to 1952. These are usually filed by years and are usually stored in anatomical order: head, neck, thorax, and so on. The recent cases (1956–57) are usually stored in alphabetical order. The cards do not need to be stored in any special order since any category can be separated with the needle in a few moments.

The simple hand punch (B) for notching the cards and the needle sorter (C), and the alignment block (D) which aids in sorting the cards are all of the equipment needed.

comments on the cards such as detailed diagnosis, small drawings of roentgenograms, and what is interesting or unusual about the case make the card of immediate value rather than merely a reference to the history. However, it is not intended that the card replace the history nor should it take more than a moment to jot down pertinent comments along with name and diagnosis when the card is started.

The first seven holes on the upper right edge (area *A*, Fig. 2) are used to identify the beginning of the patient's last name so that if someone recalls the patient's name he can quickly search the file for the history number of some other detail of the case. This portion of the card has been used widely and is essential if the cards ever need to be kept in alphabetical sequence.

An indirect code for the alphabet is used on the illustrated card so that only seven manipulations are needed to put a group of cards into alphabetical order. Instead of each letter of the alphabet having a separate hole, each part of the alphabet has a number which is punched into the card. The upper right-hand corner of the card (area *A*, Fig. 2) gives the code for the alphabetic file: *A-1, Am-2, B-3,* down to *XYZ-60.* The mechanism for this separation is very simple, even though it is not easily described. It is based on the fact that one or the sum of two of the digits *7–4–2–1* will give any number from one to nine. The right-hand *7–4–2–1* group represents units, the left-hand group represents tens. The example in Figure 2, area *A*, shows the number *4* and *1* punched in the right-hand group (units group) and the number *4* punched in the next left-hand *7–4–2–1* group (tens group). This would be number *45* and stands for the alphabetic code *RO* which corresponds to the first two letters of the patient's last name (Robinson). In order to put a group of cards into alphabetical order the needle sorter is passed through the seven holes shown in Area *A*, Figure 2, starting with the most right-hand hole and taking the dropped out cards and placing them in the rear of the

pile. Thus, it is possible to take a handful of cards and put them into alphabetical sequence in less than a minute.

The next fifteen holes at the top of the card are for anatomical classification, each hole representing a given region or system of the body. When the index was first developed the anatomical separation was very detailed, but it decreased the simplicity of the system and made the cards harder to use. The illustrated anatomical breakdown seems to be adequate for working with 1,000 to 2,000 cases annually. Each category is designed so that about equal numbers of cases will fall into each group. *Thigh* means shaft or femur from lesser trochanter to knee joint and *hip and proximal femur* means above and including the lesser trochanter.

The code is primarily for hard tissue so that when soft tissues are involved they are doubly punched in one of the three left-hand holes in area *B*. For example, if there is a ruptured biceps muscle, the *shoulder-arm* hole is punched, and also the *soft tissue, muscle, ligaments, tendon, fascia* hole. A few decisions have to be made on borderline situations such as, for example, whether the clavicle belongs with the thorax or the shoulder. It has been arbitrarily notched with the *shoulder-arm* group. The remaining holes on the top of the card are not used. This would allow for potential further coding, if desired.

The upper portion of the left side of the card is for the year of entry, (area *C*, Fig. 2) that is, the year in which the patient was treated. The cards are generally kept separated by years, but if they are mixed up for a special study they can be quickly returned to the year category by use of the needle sorter. This makes it simple to break down any condition by the year and is especially valuable for follow-up data.

In the year section (area *C*, Fig. 2) instead of having a separate hole for each year, one *7–4–2–1* group is used for coding the last digit of the year, plus a hole for the years before 1951. This makes it possible to code all the years from 1940 to 1959 with five holes. The card in Figure 2 is punched for 1948. If the hole for *prior to 1951* were not punched the year identification would be 1958. Our file has only been used since 1952 and classifies only the operative cases and other cases of interest back to 1948.

The bottom left-hand fifteen holes of the card are used for the etiology category (area *D*, Fig. 2). There is a class or group of conditions for each hole. This covers almost all of the common conditions and corresponds roughly to the major classification of orthopaedic diseases as used in the *Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death*. An attempt was made to group the diseases or conditions so that each hole would be used with reasonable frequency. Allergy, chemical toxins, metabolic, endocrine, and nutritional diseases were all lumped together because there were relatively few of each found in the case material. It also seemed worthwhile to separate the old from the new, so "old, chronic, and complication" was added. Thus, the case of a recent fracture of the hip could be separated from an old complication. The broad classification of etiology at first glance appears inadequate, but it will be found to have one chief merit—simplicity. "Congenital and developmental" are self-explanatory. "Infective, common bacteria" has been broadened to include other inflammatory conditions in which the cause was unknown, or unproved. The adjacent hole is used for virus and fungus infections, syphilis, gonorrhoea and any rare infection such as typhoid or brucellosis in which the organism is known. Tuberculosis is so common that it is given a separate hole. Trauma other than a fracture or a dislocation is classed as "miscellaneous trauma." Psychiatric, neuromuscular, vascular-collagen, blood dyscrasia are all fairly rare and so are lumped together. The last three holes on the bottom left of the card are more or less descriptive terms in which the etiology is either old or unknown.

The operations and treatment section (area *E*, Fig. 2) has been found to be of very limited value, since most of the cases can be isolated without looking up the treatment. Perhaps the only worth-while groups for coding here are: "osteotomy," "arthroplasty," "arthrodesis or bone graft." "Amputation," which is relatively rare, should not be grouped with "incision, excision" which is extremely common. Probably amputation only should be notched in this hole and incision and excision omitted.

The following additional explanatory comments may help others in making and using this type of file. *First and most important is the fact that the system must be made so that it is easy to get information out of the file.* To explain how this is accomplished a few terms need to be understood. Recall the example shown in Figure 1 where the "fracture of the femur" was sorted by two simple passings of the sorting needle. This is an example of a direct sort for which the card is best suited. The term *direct sort* means that the hole on the card stands for a particular item or group such as "thigh," and not a code number. Most users seem to be preoccupied with how to get information into the file rather than how to get it out, so they usually want to classify more items than there are holes. For this purpose codes are made which infinitely increase the number of items that may be classified, but then the cards must be separated by indirect sorting. The term *indirect sort* means that a given hole on the card does not represent one item such as "thigh", but a part of a number of a code such as the "2" of the code number "302" which might mean "thigh," for example. In using numbered codes only four holes are needed to separate fourteen items, eight holes for ninety-nine items twelve holes for 999 items, sixteen holes for 9,999 items, every four holes adding another digit.

At first glance it might seem ideal to have an elaborate code so that every possible kind of case could be separated from all others, but actually for a small file this was not found to be necessary. The additional time required for looking up code numbers, notching the code, plus the added work in sorting the cards decreases the simplicity of the system and makes it more trouble to use. (This is especially true when the major details will have already been written on the card.)

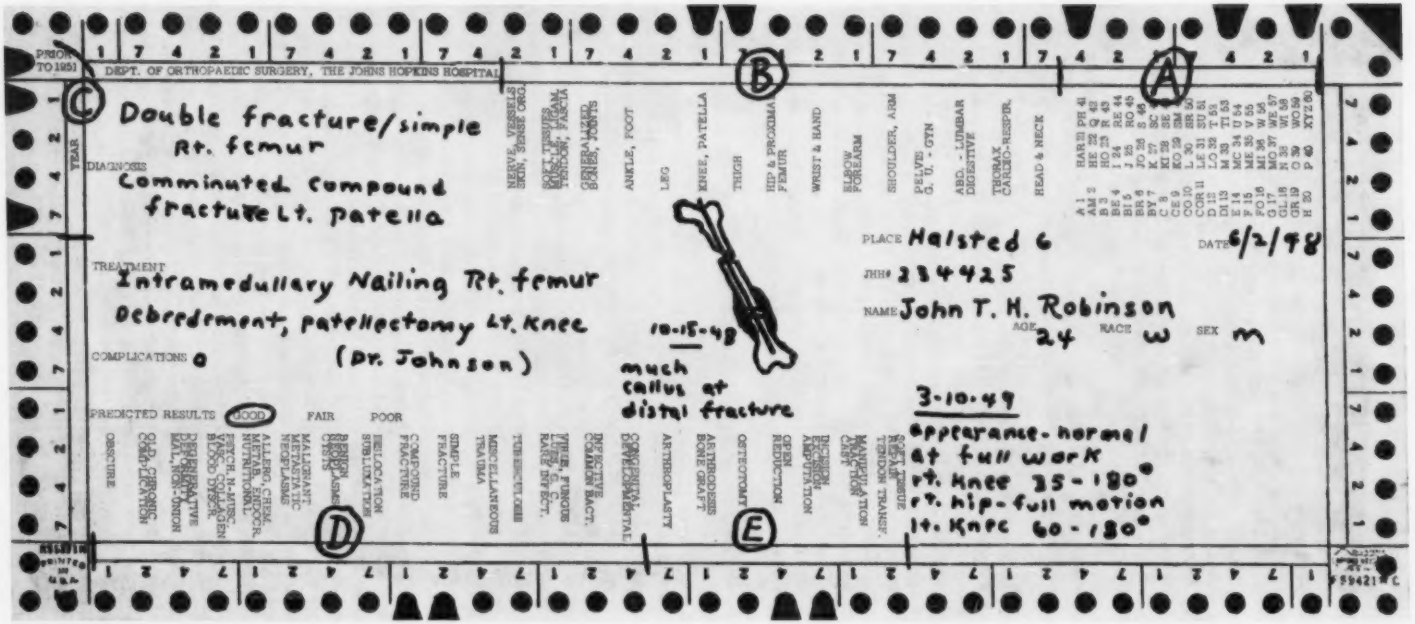

FIG. 2

Sample of the master index card filled in and punched:

A. The seven holes in area *A* are used to code the first two letters of the patient's name. Illustrated is the number 45, which stands for "RO," the first two letters of the patient's last name, Robinson.

B. The fifteen holes in area *B* are for direct anatomical breakdown. Illustrated as punched are "thigh" and "knee, patella."

C. Area *C* records the year. Illustrated as punched are 7 plus 1, or 8, and "Prior to 1951" which means 1948.

D. The fifteen holes punched in area *D* are for the etiology breakdown. Those illustrated as punched are "compound fracture" and "simple fracture."

E. The seven holes of area *E* are for operative treatment. Illustrated as punched are "incision, excision, amputation" and "open reduction."

By reading the card a fair idea of the case can be obtained, although many cards will not contain as much detail as illustrated. The card is not intended to replace the history. Its purpose is to aid in identification and classification of case material. The upper-left, lower-right, and right-hand marginal holes are not used at present and can be used for any special variation or future investigation.

If a code had three digits, 999 items could be classified, but in order to sort out any particular item the cards would have to be manipulated twelve times. It should be noted that even an experienced sorter has difficulty sorting more than 200 cards at a time. Use of the direct code permits sorting up to a speed of 60,000 cards an hour, according to the card manufacturers, and is quite obviously more satisfactory when possible.

On the other hand indirect codes are more satisfactory for sequence sorting, that is, arrangement in numerical or alphabetical order. If each letter of the alphabet had a separate hole, twenty-six holes would have to be sorted to bring the cards into alphabetical order, whereas an indirect code using six holes would require only six manipulations. In our file the alphabet is split into sixty categories and the cards are put in order with only seven manipulations.

This separates the cards into sixty almost equal alphabetic groups. The sixty-group breakdown seems to be very satisfactory for this particular size of file. If a twenty-six breakdown were used, one number for each letter of the alphabet, a-1, b-2, c-3, to z-26, the groups will probably be uneven, as there will be, for example, many more cards under S than under Z. The sixty-group breakdown takes into consideration the commoner names and provides more division of those letters in which the most names fall. For example, there are six S groups (S, SC, SE, SM, SR, and SU) whereas there is only one group for XYZ. The alphabet and year are the only classifications in our file in which an indirect method of coding is used, or in which it would be preferable.

Further details of indirect coding are beyond the scope of this article. Suffice it to say that use of numbered indirect codes for diagnosis enormously complicates the sorting of the cards for a novice. Normally, for a small file, it is much better to use a "direct" system.

Direct sorting is particularly advantageous in the anatomical and etiological categories because it is the most practical way to allow for double or multiple diagnoses. If an indirect code is used, that is, a number assigned for a condition or part, then only one condition or part may be indexed, since only one number can be punched into any group area. If, for example, 400 meant thoracic spine and 200 meant femur, in the holes assigned to anatomy, 200 or femur, could not be added to a card punched 400 since the addition would end up as 600 which would mean nothing or some other anatomical part. In direct sorting, multiple diagnoses such as tuberculosis of the spine, fractured femur or dislocated patella can all be coded on one card. In the illustrated example (Fig. 2), it can be seen that the patient had a simple fracture of the femur and a compound fracture of the patella.

The method used to index a double diagnosis using indirect codes usually requires making separate cards for each of the patient's diagnoses and unless notations are made on each of the cards of the patient's other diagnoses this information could not be obtained from the file itself. This results in a much less efficient cross index, and would seem to have little advantage over ordinary filing cards filed separately under diagnosis. Not only is it more trouble to put data into such a file, but it adds bulk and makes it more difficult to get information out of the file. For a file of this type anatomy must be separated from etiology to allow for double diagnosis, and for two other reasons.

Frequently general anatomical parts or general etiological categories are separately of interest for lecture information. If one were preparing a seminar on interesting conditions involving the hip, a code which did not sort by anatomy would not be particularly helpful. Anatomical and etiological sorting makes possible the use of much more inclusive categories for each anatomical and etiological group. Tuberculosis of the hand would be a fairly rare condition yet it could be separated with two direct sorts of the cards, even though there would be many cards punched for tuberculosis and many for hands.

In using the illustrated card (Fig. 2), it was apparent that some conditions seemed to fit more than one category, and it was necessary to set up a few ground rules so the code would notch the borderline conditions in a uniform way. For example, a case of scoliosis might be coded as a deformity secondary to leg length difference, a congenital or developmental condition, or even under virus infections as a late result of poliomyelitis. At first glance, this would seem to be a disadvantage but actually since there is little concern in sorting too much out of the file it is really not a serious problem. In general, *all the categories that seem to fit should be punched so that all possible cards drop out for each category.* A glance at the fallen cards will quickly determine whether or not the card is wanted. If, for example, in looking up infections of the lumbar spine, thirty cards drop out and of these cards five are poliomyelitic scoliosis cases, it only takes a moment to put them back into the file. In the vast majority of the operative cases it is possible to classify the etiology into one of the listed categories: "congenital-developmental," "infective-common bacteria," "traumatic," "neoplastic," "metabolic," "blood dyscrasia," and "degenerative." If the condition could fit more than one category, it is well to punch in both possibilities so that in sorting a given condition all possible available cases will be found. Vague conditions can be coded as obscure, but an attempt is usually made to avoid using this category. Certain frequent borderline conditions such as ruptured disc have to be coded in a consistent manner and a few ground rules should be made. We code them as "miscellaneous trauma" and "degenerative." Rheumatoid arthritis is classed "collagen vascular." This is perhaps the greatest defect of the system and could lead to serious sorting problems in a large file. However, for the small-group classification it has not been an important problem. It is not possible to mention all sources of confusion, but, in

general, coding with the idea of getting as many cards to fall with each category seems to be most helpful in a small file.

It should also be mentioned that the upper right-hand holes and the lower left-hand holes of the card are more easily sorted than any of the others because the cards are usually held in the left hand, by their left ends, as the needle sorter is used. The printing is designed for reading and coding by a right-handed person; that is, the printing opposite the holes is upright when the card is held in the left hand and punched with the punch in the right hand. These seemingly minor details make an important difference when working with the cards.

In a private practice or a small clinic, punch cards for each patient under current hospital treatment may be carried in the physician's pocket, and used for brief notes for later office dictation, and billing. If the patient had no pathological condition or no interesting diagnosis, no diagnosis need be punched. The current cards could be kept in alphabetical order, but eventually the "normals" could be filed separately to decrease the bulk of the cross reference index. Billing data can be easily added to this card as well as the patient's address, referring physician and other details. One simple billing addition is punching one hole when a bill is sent and then punching the adjacent hole when it is paid. Each month the unpaid bills are sorted in a few seconds. It is important to punch into the card any data that is needed to segregate the cards such as billing data to avoid the necessity of keeping any cards in a separate file or drawer. The main advantage of the system is that it permits the separation of the entire case load into any category desired using only one file and one group of cards. If it is necessary to keep one group of cards separated from the others, then the full advantage of the system is not being realized.

Punch cards are made in many sizes with greater or smaller numbers of holes and can be printed to any specification. The particular type used here was chosen for economy and for the small size which made them easy to carry in a pocket. They were the least expensive stock cards that could be purchased from the manufacturer and only the "7-4-2-1" numbers were printed on them. The hospital printing shop added the printed matter. It is not actually necessary to use printed cards. Blank cards may be used and a master card placed on top for coding and sorting. (If anyone wishes to start a trial index the author will furnish a master card on request.)

The needle-sorted index is not a panacea and there remain unsolved problems. The method merits consideration as an aid to individual orthopaedic surgeons or small clinics with similar classification needs.

A Combination Radiology—Orthopaedic Surgery System for Large Numbers of Cases

An example of a machine sorting system for large volume is the system used by the Department of Radiology of The Johns Hopkins Hospital. For several years it has utilized to great advantage an indexing system devised by Dr. Gould and Dr. Morgan particularly for their own use which employs International Business Machine sorted cards[2]. With their system the department has at its finger tips thousands of case histories and roentgenograms of every imaginable type. Over 30,000 entries are added to the system each year, yet less than an hour of work per day is required by a clerk in machine punching the information. Coded information includes the history number of the patient, clinical service, age, sex, color, part examined, cost of examination, technical quality of the roentgenograms, anatomical part, etiology, pathological proof, and interest.

The radiologist reading the film codes the quality of the film, anatomy, etiology and pathological proof and interest of the diagnosis by giving the code numbers to the stenographer who types them on the report from which the clerk machine punches the card. With an anatomy and etiology code chart the radiologist can dictate the code numbers for each case in a fraction of a minute. For their use a separate anatomy and etiology breakdown has proved to be essential. Every three months their cards are sorted into diagnostic categories in preparation for machine tabulating. This procedure results in a printed book which includes the history numbers of all abnormal cases indexed under the various diagnostic entries both by etiology and anatomy. The quarterly index book has not only been a pool of their radiological experiences for clinical study and research but has been the foundation for departmental postgraduate, resident, and medical student teaching.

Since practically every bone and joint case is x-rayed the Orthopaedic Department is able to obtain statistical information from these cards such as total number of fractures or all cases x-rayed having slipped capital femoral epiphyses. An Orthopaedic Department closely associated with a Radiology Department may find that a system of this type would better handle their needs with a moderate shared expense. This would allow for finer breakdown of categories and addition of more statistical data which should be valuable for very large clinics or departments. Machine sorting appears less adaptable to the "impromptu" demands of our small file such as picking out an interesting case for a lecture or looking up an individual history, chiefly because neither the machinery nor the trained operators are needed to use the system. The quarterly index book is less personal since it consists of pages of columns of numbers rather than written notes and does not identify an individual case, although one can tell from the code numbers the quality of the roentgenograms, pathological proof, and roentgenological interest of each case. The quarterly index books are of

inestimable value not only to the Radiology Department, but also to many other departments of the hospital, particularly when all of the cases of a given condition coded by x-ray are to be studied.

Very Large Volume Systems

An example of the type of system for very large numbers of cases is the one used for all records of the hospital. Machine sorting systems have been studied and used extensively for many years by the statistical department of The Johns Hopkins Hospital. Dr. Crosby formulated a code which was used here (1926–51) and in the Veterans Administration. Dr. Bachrach found that there were certain definite advantages, however, in changing over to a system using the *Manual of International Statistical Classification of Disease, Injuries, and Causes of Death* to which was added a punch typed notation of the diagnostic terms on International Business Machine punch cards (Fig. 3). This two-volume code has the advantage of many years of universal trial and revision and contains a most remarkably complete alphabetic cross-reference index. This makes it possible to code in a much more uniform manner. However, this code contains a smaller number of groups than most other classifications and therefore each group is more general and contains a fair number of related but different conditions. Request for histories may be general, such as a request for malignant bone tumors, Code 196; but frequently the request might be for a specific condition such as Ewing's tumor of the tibia. If the card contained only the international code number 196, it would be necessary to consult all the histories of malignant bone lesions to obtain the Ewing's tumors of the tibia.

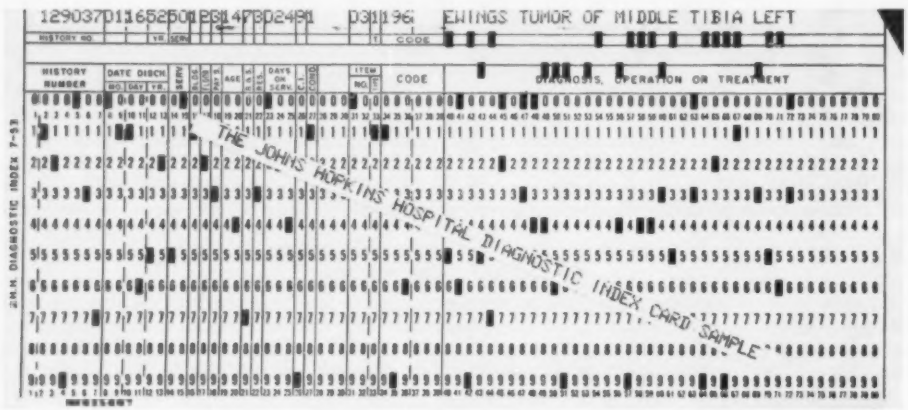

Fig. 3

Illustrated is a sample punched card used by the statistical department of the hospital for coding all in-patients. The code number "196" at the top of the card stands for malignant bone tumors, a fairly general category. To the right of this code number is a typed notation of the more complete diagnosis and location which reduces the necessity of looking up all the records coded 196 to obtain Ewing's tumors of the tibia. The left side of the card gives valuable statistical data for the hospital administration.

The purpose of having the diagnostic terms punched into the card is to reduce the necessity of checking the clinical record to ascertain the specific nature of the case. To make this possible each diagnostic card should contain information about the etiology and site of illness or lesion. This information should be as complete as possible within the limits of the card space. Many abbreviations are possible, and a glossary of abbreviations has been developed[1]. If two or more concepts are contained in the diagnosis, the indexer may make more than one card, but each refers to the other. For example, a case of carcinoma of the breast with bone metastasis would have two cards: (1) 170—carcinoma breast, bone metastasis. (2) 196—bone metastasis from breast carcinoma. Both individual cards, however, will state the second concept.

By this system it is possible to index several hundred thousand patients' histories, but it requires the employment of a full-time statistical staff capable of coding a large volume of material. Such a large system seems to operate best if coding and sorting are carried out by a small number of trained individuals, because uniformity is essential to large statistical analyses.

Summary

Three methods of indexing orthopaedic surgery patients have been presented together with some of the problems. The small file is discussed in more detail since it should be of more general interest. The other methods are mentioned principally to demonstrate more clearly the reasons why certain types of codes have specific advantages in special situations. No system is better than the individuals operating it. A cumber-

some method would be more effective in the hands of a dedicated person than a well-designed system operated casually by the uninterested. Active interest and participation by the persons working with the cases is needed for success. It is hoped that some of our mistakes may be avoided by prospective indexers reading this article.

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LETTERS TO THE EDITOR

To the Editor:

Attention has recently been called to an error in our article "Bipedal Rats and Mice. Laboratory Animals for Orthopaedic Research" which appeared in the June 1957 issue of *The Journal*, pages 616–622. On page 620, in the last two lines, the sentence reads: "Since rickets is not possible in the rat, the knock knees were significant". This wording of the sentence was unintentional; the statement is obviously incorrect. The sentence should have read: "Since rickets was not possible in our rats, the knock knees were significant". We fed the animals on the usual balanced laboratory chow and could not find any indications of rickets in those operated upon nor in their litter mates used as controls. This ruled out rickets as a possible cause of the knock knees.

Charles W. Goff, M.D.

To the Editor:

An article by D. M. Bosworth on the use of the semitendinosus for instability due to injury to the tibial collateral ligament was published in the January edition of the American Volume of *The Journal of Bone and Joint Surgery* of 1952. On page 201 under "Comment" he quotes: "It may well be that without our knowledge others have preceded us with reports of such operative repair, published or unpublished". No reference is made to the original work of T. P. McMurray. A very clear description of the use of the tendon of the semitendinosus is found in his textbook, *A Practice of Orthopaedic Surgery*, Ed. 1, 1937, and Ed. 2, published by Edward Arnold & Co. of London, 1943, page 46.

In a recent article on this subject in the April 1957 edition of the American Volume, Vol. 39-A, No. 2, page 304–308, Capt. R. L. Fenton speaks of the Bosworth Operation with reference to the January 1952 article in the same Journal.

It may be that McMurray's text has not been widely read and that others besides the above-noted authors are unaware of his earlier description of this operation. I have known and made good use of it since I had the privilege of visiting the late T. P. McMurray at Liverpool in 1942. It is of considerable value also in the grossly unstable knee where rupture of one or both cruciate ligaments as well as the tibial collateral, has occurred.

H. H. Boucher, M.D.

Editorial

During a long life I have met two physicians to whom I could fittingly apply the term *great*—Robert Jones and Sterling Bunnell. Very different they were in many respects, but they were alike in that unusual quality of greatness. By that I mean a bigness, an eminence, a touch of genius, a kinship with Prometheus who for the sake of mankind was willing to risk his very life. Both gave themselves utterly to their profession and each one, in his own way, contributed immeasurably to the advance of orthopaedic surgery and to the rehabilitation of the handicapped. Both began their work as general surgeons. It was not until the First World War that Bunnell evidenced his interest in tendon surgery. When, however, in January 1918 his article on tendon surgery appeared in *Surgery, Gynecology and Obstetrics*, it was at once evident that a great master of a new surgical specialty had arisen. From then until his recent death, one brilliant paper succeeded another, each one replete with new ideas, each opening up new vistas of surgery hitherto undreamed of. As for his *magnum opus*, his volume *Surgery of the Hand*, published in 1944, it has correctly been called "The Hand Surgeon's Bible." It has already become a classic and will unquestionably remain one in the evolution of surgery.

This book truly expresses the personality, the scholarship, the versatility, the surgical ingenuity, and the vast experience of Bunnell. Unlike many medical texts it is original from cover to cover. There is no book in any language which can compare with it, for it has actually created a new branch of surgery. The more I study it, the more deeply impressed I am by the great range of Bunnell's knowledge, his accuracy of observation, the lucidity of his style, his unswerving honesty, his infinite patience and attention to detail, his thoroughness in diagnosis and after-treatment, as well as skill in operative technique, his deep regard for the patient's welfare. There is no aspect of hand surgery about which he has not written in a new creative spirit.

And yet, so humble and modest was Bunnell that he was not satisfied with his great contribution, and was constantly striving to improve it, by adding new ideas, new experiences. This was indeed the nature of this great man, in whom there was no conceit, but a childlike simplicity combined with amazing skill and wisdom.

Like Lord Lister, Bunnell was shy and retiring. He never became involved in discussions about priority. He was not argumentative but he knew how to present his own views with conviction. He taught by example, and his many students agree that he was a teacher of the highest rank. It was during the Second World War that as consultant in Hand Surgery to the Surgeon General he gave up his own practice and devoted himself for three years to instruction in hand surgery in the nine centers established in Army General Hospitals throughout the country. This unselfish activity resulted not only in a vast improvement in methods of treatment, but in the formation of a group of young surgeons deeply interested in hand surgery. These men formed the nucleus of the American Society for Surgery of the Hand of which Bunnell became the first President.

Bunnell never stopped creating. Each operation was a new experience, each patient was viewed as a new problem to which he was willing to give special consideration. He delighted in new ideas, and was particularly pleased with each original contribution of his colleagues, provided that it passed his critical analysis. He was generous to a fault, objective in his appraisal of his own work as well as that of his fellows. In many years I never heard him make an unkind remark about one of them.

We have suffered an irreparable loss in his death, but we have learned so much from his life that we are deeply thankful for the years he has spent with us. We grieve but we exult in the gift to mankind of Sterling Bunnell.

Leo Mayer

STERLING BUNNELL
1882–1957

Dr. Sterling Bunnell, world renowned surgeon, teacher, and author of *Surgery of the Hand* died at his home in San Francisco on August 20, 1957. His death ended an active life of scientific inquiry and accomplishment.

Dr. Bunnell was born in San Francisco in 1882, the son of James Sterling Bunnell and Catherine Mapes Bunnell. The beginning of his scientific endeavors came early. At the age of six years he was starting to probe into the mysteries of animal life and this intense interest led him deeper into the field of anatomy and the natural sciences as he grew into manhood. His accomplishments in this field alone were outstanding.

Entering the University of California, he obtained his academic degree in 1904 and his medical degree in 1908. For a time thereafter, he was associated with the University but later entered private practice in San Francisco, where he was to remain throughout his lifetime.

Early in his medical career he recognized the undeveloped state of extremity surgery and was soon deeply engaged in extremity surgical problems in the laboratory where he carried out extensive experimental work on tendon and nerve sutures and grafts and on skeletal structures and joints. The basic facts thus learned were to be used later in restoring function to vast numbers of human crippled extremities.

During World War I, Dr. Bunnell served as a medical officer in the United States Army from May 1917 to March 1919, holding the rank of Captain. He was associated with Base Hospital No. 47, and saw action

in France while a member of Operating Team 101. During this time, he developed a keen interest in aviation, and, on his return to San Francisco, he piloted his own plane, using this means of transportation to travel to nearby cities for consultation or surgery up until 1926. He was at one time President of the National Aeronautical Society of the West, and in local circles he was frequently referred to as the "flying surgeon". As further evidence of his aviation interests, he published in 1930 a most interesting treatise entitled *Aeronautics of Bird Flight.*

During his military service, his professional contacts with the wounded further stimulated his interest in the reconstructive aspect of surgery, and many of the challenging problems at this time were to be solved later by his own efforts.

On his return home he engaged in a general surgical practice. He was adept in all surgical procedures, encompassing all of the surgical specialties as they exist today. As examples of his diverse interests and attainments he published on such topics as cleft-palate repair, arterial suture, a positive pressure apparatus to be used during thoracotomy, and a guide for the Smith-Petersen nail.

His first publication on the upper extremity came in 1918 and was entitled "Repair of Tendons in the Fingers and Description of Two New Instruments". Following this and at intervals during his lifetime, he produced over fifty papers covering many aspects of reconstructive and plastic surgery. These original contributions encompassed such subjects as atraumatic technique, physiological reconstruction of the thumb after total loss, the pull-out suture, nerve grafts for repair of extremity nerves and the facial nerve, active splinting, intrinsic-muscle contracture of the hand, tendon transfers for the upper extremity, plastic aspects of reconstruction, surgery of the rheumatic hand, and many others.

In 1944, the First Edition of the monumental book, *Surgery of the Hand,* was published. In this text, Dr. Bunnell carefully and exactly documented the principles of reconstructive surgery which are applicable to all parts of the body, although the main emphasis was directed toward the upper extremity and hand. Revised editions in 1948 and again in 1956 were in keeping with the rapid developments in hand surgery during World War II, in the immediate post-war years, and subsequently. He was eager to keep this publication up to date.

Surgery of the Hand rapidly achieved world-wide distribution and was translated for publication in the Spanish and German languages. The book is and will continue to be a contribution never to be forgotten in the annals of medical literature.

Shortly after the outbreak of World War II, Dr. Bunnell was called into service as civilian medical consultant by Dr. Norman T. Kirk, then Surgeon General of the United States Army. During his tour of duty, which was over a three-year period, he organized and established nine hand centers in Army General Hospitals throughout this country. His untiring efforts resulted in great advance in the handling of wartime hand injuries and their later reconstruction. He visited each hand center periodically, holding clinics, performing surgery, and training innumerable medical officers to carry on the work. For his outstanding service to the Army he received the United States Medal for Merit.

Broad military contacts resulted in a development of great interest in the field of hand surgery, particularly among the younger men in the service, and culminated in the organization of the American Society for Surgery of the Hand in 1946. Dr. Bunnell served as the Society's first President. Up to the time of his death he continued as its guiding force and as a source of inspiration to its members. In addition, he was instrumental in encouraging the formation of hand clubs or societies in Scandinavia, England, South America, and Japan.

After the war, and with some misgivings, he gave up his general surgical practice to devote his full time to reconstructive surgery.

To the casual observer, Dr. Bunnell appeared quiet, almost retiring in nature. To his closer acquaintances, however, he was dynamic and untiring. He was blessed with great physical stamina which served him well, both in his prolonged hours of study and work and on the many rugged hunting, fishing, and collecting trips which were his particular pleasure and source of relaxation. His modesty and lack of fear were among his dominant characteristics. He displayed great warmth of personality and to his immediate contemporaries he was affectionately known as "Bunny."

He was for many years a member and active participant in the Olympic Club and in the Bohemian Club of San Francisco.

Professionally, Dr. Bunnell's life was characterized by complete devotion to the science of surgery. He was a master of comparative and human anatomy, subjects which to him were of living and vital interest. His surgery was clever, fast, and accurate. He was never thwarted by an unexpected condition or event, and he strove untiringly for perfection in his work. His judgment was unerring and his decisions were promptly executed. His thinking was always along the lines of basic principles, the details to fall in line as a natural expression of his skill. He was never a defeatist; he was always hopeful, no matter how serious or complicated the case. His searching mind and the ready application of new ideas kept him from being mired in stereotype procedures, thus ensuring his rapid advance in his chosen field.

With his associates, he stressed the same sound principles of surgery he practiced himself and was critical if his student failed to rise to this standard. As a result, he has left us not only the fruits of his labors in the

way of scientific accomplishment, but the inspiration which he so dynamically displayed during his lifetime. Through his efforts, surgery of the hand has been nourished and developed to the state of world-wide recognition it enjoys today.

The acceptance of his scientific and surgical accomplishments came early, both in this country and abroad, as evidenced by society memberships and awards. He was a licentiate of the American Boards of General, Plastic, and Orthopaedic Surgery. He was an honorary member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, the Western Orthopaedic Association, the California Society of Plastic Surgeons, the Sociedad Latino-Americana de Ortopedia y Traumatologia, an honorary fellow of The British Orthopaedic Association, a foreign corresponding member of the Societas Ortopedica Scandinavica. He was a member of the American Surgical Association, American Association of Plastic Surgeons, American Society of Plastic and Reconstructive Surgery, American Association for the Surgery of Trauma, American Society for Surgery of the Hand, and an emeritus member of the Hand Club of Great Britain. He was a Fellow of the American Occupational Therapy Association (1951–1953).

He was consultant to the Surgeon General of the United States Army ,to the United States Navy, and to the Alaska Department of Health. He received the United States Medal for Merit, Ordre National de la Legion d'Honneur, and Ordem Nacional do Cruzeiro do Sul.

He was a member of the Sigma Nu medical fraternity and the Sigma Xi scientific society. In San Francisco, he was a staff member of the Stanford University Hospital, the St. Francis Memorial Hospital, and Children's Hospital.

Dr. Bunnell is survived by his wife, Elizabeth Bunnell, and a son, Sterling Bunnell, Jr. His son, now in medical training at the University of California, shared his father's interests and was a close companion on many of his trips afield.

As time passes since his death, one realizes more and more the magnitude of the man. His loss is felt whole-heartedly and deeply by his associates of the profession, and by his many close personal friends and hunting and fishing companions. The name of Sterling Bunnell is destined to be one of the great names in the profession for posterity.

L. D. H.

SAMUEL KLEINBERG
1886–1957

During the night of September 6, American orthopaedic surgery lost one of its stalwart pioneers, Dr. Samuel Kleinberg. Born in 1886, he graduated from the Columbia College of Physicians and Surgeons in 1908 and soon thereafter began to work under Royal Whitman at the Hospital for the Ruptured and Crippled. Thus began a most unusual friendship. To almost all his assistants, even to his own son, Whitman was noted for his acrimonious tongue-lashing, but to Kleinberg he never said an unkind word. Perhaps that was because he recognized in Kleinberg a disciple whose love and loyalty far exceeded that of any other man on his staff. To Kleinberg, Whitman was an orthopaedic god. Good though this was in some ways, his devotion to the teachings of Whitman tended to retard his adoption of the newer methods which came into being during the nineteen-twenties and early thirties. Thus for years Kleinberg fought against the use of the Smith-Petersen nail; his argument was simply that Whitman treated fractures of the femoral neck by plaster-of-Paris fixation in abduction and internal rotation. So why use a nail? Likewise, he had no use for the Hoke stabilization, since to his mind it could not compare in effectiveness with the Whitman astragalectomy. From Whitman he learned thoroughness, accuracy of diagnosis, and meticulous surgical technique. Those were the days when the strap-and-buckle methods were being rapidly replaced by the use of the scalpel and of the electric bone saw. Kleinberg soon became a most skillful operator, combining speed with accuracy.

It must not be thought that Kleinberg devoted himself exclusively to advocating the Whitman school of orthopaedic surgery. Very early in his career he became interested in scoliosis. When Abbott published his method of treatment, Kleinberg visited him in Portland, and was one of the first to set up an Abbott frame

in New York. He was also one of the first to realize the dangers and the inadequacy of the Abbott method. He had studied the pathology of scoliosis and helped Whitman to write the chapter on scoliosis in his great textbook. Impressed by the results of the spine fusions of Albee and Hibbs in the treatment of Pott's disease, Kleinberg was one of the early advocates of spine fusion for scoliosis, but, dissatisfied with his results he later preached restraint in the use of this method. He pioneered in experimenting with heteroplastic-bone implants and attempted many spine fusions with boiled beef-bone grafts.

In 1924 he was elected a member of The American Orthopaedic Association, and in 1934 he was one of the founders of The American Academy of Orthopaedic Surgeons. When, in 1929, The American Orthopaedic Association met in New York on its way to England to hold a joint session with The British Orthopaedic Association, Kleinberg was the efficient chairman of the committee on local arrangements, including the program on shipboard. His speech at the banquet was so witty that it drew peals of laughter even from the dignified Dr. Goldthwait.

In the late twenties, Dr. Kleinberg joined the staff of the Hospital for Joint Diseases as Attending Orthopaedic Surgeon; then began the most fruitful portion of his professional life. He struck out boldly for himself, wrote many excellent scientific papers, and conducted his service with due regard for the welfare of the patients and the instruction of his staff. It was then that he began to show one of his most endearing traits: a deep interest in the younger men on his staff and an active desire to help them. One of these men (Dr. Edgar M. Bick) has written of him: "He was supremely loyal to the men on his staff, constantly urged them to investigative work, and above all supported them in their endeavors—if their objects were sincere—as few other chiefs have. A number of his students hold positions of consequence today because of his efforts on their behalf. On several such cases, his own effort to establish his younger students represented a real sacrifice to himself. He never hesitated and his men never forgot."

Of his scientific contributions, the most important were his two volumes on scoliosis. In these he gave account of his own vast experience. A young orthopaedic student wrote of them "I never understood scoliosis until I read Kleinberg's book." He was indeed a master of exposition.

Until within a few weeks of his death Dr. Kleinberg continued in active practice. He had a host of devoted patients, hundreds of whom came to his funeral service. Now they feel bereft of a friend as well as of their physician. At the Hospital for Joint Diseases he will be sadly missed, for even though he had reached the retirement age, he was constantly in demand as consultant, and he remained the active editor-in-chief of the Bulletin which he had founded in 1940. To his many friends and colleagues Dr. Kleinberg's death "leaves a lonesome place against the sky".

L. M.

GEORGE WAGONER

1896–1957

Dr. George Wagoner had returned to his home in Johnstown to spend a weekend with his mother and his sister. On April 29, he and his sister were fishing in the morning at the Rolling Rock Club. In the afternoon, he was accompanied by his cocker, Witte; later that day (his watch had stopped at 3 P.M.), Dr. Wagoner and his dog were found downstream. It is presumed that Witte fell or jumped into the current, and Dr. Wagoner, in attempting a rescue, died of a coronary occlusion. This chance he took was so characteristic of the man who moved rapidly to another's aid without fear of personal hazard. His really soft heart was covered by a gruffness which too few of his colleagues were privileged to penetrate.

George Wagoner was born in Johnstown, Pennsylvania, the son of Gertrude Suppres and George W. Wagoner, M.D. His interest in medicine was stimulated early when he accompanied his father in making house calls on a general practice. He told stories of assisting his father by giving anaesthesia for operative procedures which were carried out on kitchen tables. His father also served as a Democratic Mayor of Johntown. Dr. Wagoner attended the College of the University of Pennsylvania and entered Medical School at the same institution. The latter training was interrupted by his enlistment in the Ambulance Corps in 1917. Upon return to medical school, he devoted considerable time to independent research. He developed a method for measuring blood flow through application of the Venturi meter principle. For this work he was elected to membership in Sigma Xi. After graduating in medicine in 1922, he was an intern at the Philadelphia General Hospital. Here, he was awarded the first John Hunter Fellowship at the University of Pennsylvania for training in experimental surgery. Here, he met an intern, Marjorie S. Jefferies, M.D.; they were married at the completion of their internships. His experimental surgery was carried out under the direction of Dr. Joshua E. Sweet. Apart from his exeprimental work in the animal laboratory, he developed a great interest in bone pathology. In 1929, and again in 1934, he worked at the University of Innsbruck under Professor Lange. He mastered the technique of making microscopic sections of an entire bone lesion. These large slides were greatly

admired and appreciated by visitors to his laboratory, as well as stimulating to undergraduate and graduate students in bone pathology.

He was Director of Orthopaedic Research and Professor of Orthopaedic Pathology in the Graduate School of Medicine in the University of Pennsylvania. A few titles of his publications show the breadth of his medical knowledge: the work on cholesterol embodied in "Gallbladder, Past, Present, and Future" (1925); "Clinical and Experimental Investigation in Spinal Anaesthesia" (1926); "Osteoperiosteal Grafts" (1926); "Use of the Draughtsman's Curve Ruler in Making Tracings of Spinal Curvatures" (1927); "Roentgenographic Measurement of Objects by Means of Screens Interposed Between Object and Film" (1928); "Handbook of Experimental Pathology" (1932); "Intrinsic Circulation of the Vertebral Body, with Roentgenologic Consideration" (1932); "A Comparative Study of the Various Techniques for Preparing Bone Specimens for Museum Presentation" (1935); "The Anterior and Posterior 'Notch' Shadows seen in Lateral Roentgenograms of the Vertebrae of Infants", (1939); and "Studies in the Metabolism of Articular Cartilage. Respiration and Glycolysis of Cartilage in Relation to Its Age."

Dr. Wagoner had many interests. He enjoyed hunting as well as fishing for which he had traveled in the more remote districts of the United States and Canada. He was an amateur carpenter, cabinetmaker, and collector of antiques. He liked to think up gadgets and build models. Only last year, he designed and built a model turbine for which a patent search was made. This disclosed that such a patent had previously been issued to George Westinghouse.

Dr. George Wagoner served as a Commander in the United States Naval Reserve during World War II. He was attached to the Marine Corps at Parris Island, and saw duty on the Hospital Transport Ship, *U.S.S. Pinckney*, assigned to the Pacific theater. Dr. Wagoner was attending surgeon at the Graduate Hospital of the University of Pennsylvania, the Bryn Mawr Hospital, where he served as Chief of Staff, 1950–51, and was consulting orthopaedist to Bryn Mawr College, Pottstown Hospital, and Women's Hospital of Philadelphia. He was Director of the Medical and Health Division of Montgomery County Civil Defense and Co-chairman of the Eastern District of Pennsylvania Civil Defense. He was a member of the following societies: the American Medical Association, The American Orthopaedic Association, Halstead Society, Philadelphia College of Physicians, Philadelphia Orthopaedic Club, and Société Internationale de Chirurgie Orthopédique et de Traumatologie.

J. T. N

ROLAND E. HAMMOND

1875–1957

On June 11, 1957, The American Orthopaedic Association lost by death one of its older and most loyal members, Roland E. Hammond of Providence, Rhode Island. He was eighty-one years old. In 1936, he was elected Vice-President of the Association. Although he lived in Providence, his regular attendance at the Boston Orthopaedic Club meetings was appreciated by his being made its President in 1926. He was Chairman of the Rhode Island Regional Committee on Fractures of the American College of Surgeons, he was a delegate from Rhode Island to the American Medical Association, and a Fellow of The American Academy of Orthopaedic Surgery. He was a diplomate of the American Board of Orthopaedic Surgery. In Rhode Island he had been President of the Rhode Island Medical Society and the Providence Medical Association and was a member of the Providence Medical History Club and a delegate from that Club to the American Association of the History of Medicine.

His hospital connections were many. He was Consulting Orthopaedic Surgeon at the Rhode Island and Saint Joseph Hospitals and at various times headed the department of orthopaedics at the Miriam Hospital in Providence and was consultant at several other hospitals in Providence, Wakefield, Westerly and Newport.

He was in World War I as a medical officer in Newport, Ireland, and London, England; he was a Lieutenant Commander in the Navy from 1934 to 1938.

He graduated from the Brockton, Massachusetts High School, and in 1898, from Tufts College. He received his medical degree from Harvard in 1902.

As an author he wrote some fifty monographs on orthopaedic subjects and articles on the history of medicine.

ROLAND E. HAMMOND

His hobbies were ornithology, art, gardening, music, and travel. He was most interested in the study of Sherlock Holmes. An ardent collector of items relating to the life and times of Holmes, he was a member of the New York and Boston societies devoted to the study of Sherlockiana.

To his friends who knew him best he will always be remembered as an inspiration because of the way he faced an incurable disease. In spite of his increasing physical difficulties he continued as long as it was possible to go to medical meetings, especially those of The American Orthopaedic Association. To be able to carry on in spite of disability shows the indomitable spirit that made it possible for him to do so much in his chosen field. He lived a long and useful life and the world is a better place for his having lived in it.

L. T. B.

HAROLD RUSSELL CONN

1889–1955

The death of Harold R. Conn removed a most colorful and inspiring figure from orthopaedic surgery. His warm handshake, his friendly word of greeting, and a liberal supply of stories and jokes told exceedingly well, coupled with his great skill and natural ability, will be sorely missed.

Harold R. Conn, sixty-six, retired medical director of all Goodyear Tire and Rubber Company domestic plants, and widely known Akron orthopaedic surgeon, died Thursday, December 5, 1955, in San Francisco. He was born in Blairstown, Iowa, on January 31, 1889. He graduated from Washington High School, Cedar Rapids, Iowa, in 1908, from Jefferson Medical College in 1912, and served his internship in the Delaware Hospital, Wilmington, Delaware. Upon completion of his internship, he did postgraduate work in Boston and in Edinburgh, Scotland.

He practiced for four years in Cedar Rapids, Iowa. With the entrance of the United States into World War I, he entered service in 1917 and was attached to the American Expeditionary Forces in Europe. He was then loaned to the British Army in which he studied under Sir Robert Jones and Sir Harold Stiles. Later, he served in France and in the United States and came out of the service with the rank of Captain. He received a decoration for the Meuse Argonne and Defensive Sector. After the war, he was Chief of the Amputation Service at Walter Reed Hospital, Washington, D. C., for a year, and he then went to Akron, Ohio, to open private practice in orthopaedic surgery. He became Chief Surgeon and later Medical Director of the Goodyear Tire and Rubber Company. During World War II, he was appointed Orthopaedic Consultant to the Fifth Service Command. He was a member of the Committee on Military Orthopaedics of the National Research Council and was one of the organizers of a committee to develop better artificial limbs. He acted as a consultant to the various amputation centers in the United States. Dr. Conn was the author of a number of monographs on orthopaedic subjects and joint author of two textbooks in Orthopaedic Surgery. His best known work is "The Battalion Medical Officer" which was distributed to all medical officers in World War II.

Following World War II, Dr. Conn, now an invalid, suffering from chronic asthma complicated by heart disease, retired to Oakland, California. There he was able to assume the duties of Orthopaedic Consultant

to the Veterans Hospital in Oakland. At this time he became interested in refrigeration anaesthesia for amputation and performed several amputations with this type of anaesthesia. Dr. Conn invented an adjustable bone clamp and a reduction frame for ankle fractures. In 1944 in conjunction with the Goodyear Tire and Rubber Company, he developed one of the first pneumatic tourniquets. It was used extensively by the Army and Navy in World War II.

Dr. Conn was a member of the American Board of Orthopaedic Surgery, a Fellow of the American College of Surgeons, a member of The Academy of Orthopaedic Surgeons and a former Vice-President of The American Orthopaedic Association. He was given the Meritorious Award by the Goodyear Tire and Rubber Company in 1944.

As a teacher and counselor of young men he was at his best and no problem was too great or too trivial for his close attention. His passing is mourned by all who had the privilege of knowing him. He is survived by his wife, Sarah Husband Conn of Akron, Ohio, and nephew, Colonel John Asby, an orthopaedic surgeon in the U. S. Army currently serving in Japan.

J. R. M.

Proceedings

THE AMERICAN ORTHOPAEDIC ASSOCIATION

ANNUAL MEETING — THE HOMESTEAD, HOT SPRINGS, VIRGINIA
JUNE 24 TO JUNE 27, 1957

Femoral-Neck Fractures. Pathogenesis of Avascular Necrosis, Non-Union, and Late Degenerative Changes. DR. SHERMAN S. COLEMAN [1] and DR. CLINTON L. COMPERE [2] secured surgically sixty femoral heads between twenty-four hours and eleven years following trauma. Each specimen was placed in formalin shortly after removal, and each head was hemisected at the level of the ligamentum teres. A roentgenogram of each hemisected specimen was made, and the specimen was decalcified and embedded in celloidin, sectioned, and stained with hematoxylin and eosin. These sections afforded material for histological study. The preoperative roentgenograms were studied and compared with roentgenograms of the surgical specimen. The histological features were then correlated.

The first observations were on acute fractures twelve hours to twenty-one days after trauma. Some evidence of bone necrosis was discernible in all heads during this period. Osteogenesis was noted between the fourth and twelfth day after fracture; between the tenth and twenty-first day osteogenesis was often abundant. The bone was deposited in three different ways: (1) on older trabeculae, particularly in the fovea region (2) within granulation tissue, and (3) in healing callus of the fracture and at the fovea centralis. The new bone apparently served to unite the fracture, to replace dead bone, and to reorganize the bony structure of the femoral head. In the heads that were three to eight weeks old, extensive necrosis was first noted and there was a greater tendency for the head to be totally dead or totally alive. It is believed by the authors that non-union of the fracture is more likely a cause of complete avascular necrosis of the head than a result of it. From two to six months the basic histological findings are similar to those encountered in both viable and necrotic heads from earlier non-union. The histological features of non-union were easily discernible in the head, either living or dead.

Comments concerning roentgenographic density are as follows: "A relative increase means that the femoral heads appear of greater density because the surrounding normal bone is less dense. An absolute increase probably indicates that an addition of new bone has occurred." The authors conclude that roentgenograms do not enable one to establish accurately the viability of the head or to predict the fate of the head if union is achieved by surgical interference.

From the group of fractured femoral heads, six months to eleven years after fracture, the authors concluded that in the absence of infection, tumor, or local disease, non-union of the femoral-neck fractures should be uncommon if fragments are accurately apposed. They pointed out that, at the worst, the head represents an ideal autogenous cancellous bone graft. Non-union is due not only to lack of contact, but also to poor internal fixation. In union with degenerative changes, there exists very poor circulation of the femoral head. Collapse and invagination of the weight-bearing portions of the articular cortex and overlying cartilage is the most striking feature.

In conclusion, the authors believed that some degree of bone necrosis occurs in all femoral heads following intracapsular fracture, and that total necrosis of the femoral head rarely occurs in the first three weeks following fracture. After four weeks, if not united, the femoral head is undoubtedly living or necrotic and changes in the contour of the ununited femoral head, living or dead, are uncommon. The earliest changes in the roentgenogram usually appear around two months. The roentgenograms do not permit one to predict accurately the viability of the head in all cases.

Introduction of Circulation into the Necks of Femora. DR. CHARLES J. FRANKEL [3], DR. W. CLARKE POLE [4], DR. PAUL DERIAN [5], and DR. DAVID V. STRIDER [6] reported work based on the studies of Tovee and Gendron in which the neck of a dog's femur was fractured, the head replaced, fixed with a screw, and concentrations of radioactive phosphorus uptake by the head determined. The authors had assured themselves of interference with the blood supply by a more extensive stripping of vascular structures at the trochanteric region and utilized muscle grafts to the subcapital region in an endeavor to restore the

[1] Shriners' Hospital for Crippled Children, Salt Lake City 3, Utah.
[2] 720 North Michigan Avenue, Chicago 11, Illinois.
[3] University of Virginia Hospital, Charlottesville, Virginia.
[4] 132 West York Street, Norfolk 10, Virginia.
[5] 1040 Delaware Avenue, Marion, Ohio.
[6] 801 East High Street, Charlottesville, Virginia.

(*Continued on page 1429*)

President's Address*

BY DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

Your President has been fortunate enough to inherit, through several sources, a complete set of the published *Transactions of the American Orthopedic Association.* In order to obtain a better perspective of the present function of the Association and of its future role, may I be permitted briefly to refer back to these Transactions. Through interpretation and interpolation I will note the original purpose of the Association, indicate the nature of the original meetings and the type and quality of discussions that took place. Later I will compare with them the present activities and possibly denote some aspirations for the future or modification of existing programs.

"The formation of an American Orthopaedic Association was first formally discussed at a meeting of gentlemen interested in the subject held at the house of Dr. Shaffer in New York, January 29, 1887. Dr. Gibney and Dr. Shaffer had independently formed plans for the organization . . .

"Dr. Shaffer spoke of the need of such an Association not only to bring together American orthopaedic surgeons, but also to secure a better recognition in Europe for American orthopaedic surgery.

"The question was discussed at some length by the gentlemen present and a rising vote was taken, which resulted in ten votes for the formation of such an Association and two against it: two gentlemen did not vote on the question." [1] Dr. Virgil Gibney, as Temporary Chairman, appointed a Committee of Three to draw up a constitution and by-laws.

The original constitution and by-laws occupy a space of only three and one-half printed pages. Several interesting things appear. In the first place this brief constitution is extremely succinct. At that time and for the purposes stated, it appeared to be entirely adequate. The most important portions of it are still in effect.

The Membership Committee, its purposes and autonomy, remain the same. The officers are the same. The meeting times, proposal for publication of papers, order of business, by-laws and standing rules including the length of time of presentation of papers, are essentially identical. The purpose of the Association was stated to be "*the advancement of orthopedic science and art.*"

Membership at that time, however, was possible at a much lower age and required only that a "doctor be engaged in the practice of medicine for at least three years, and shall have given evidence of satisfactory scientific attainments." Since this was qualified by a statement that a forfeiture of membership should be declared "in the case of any member who ceases to exhibit an active interest in the science of orthopaedic surgery," one may rest assured that general practitioners were not encouraged to apply!

Evidence of intent of the Founders that this should be an American Orthopaedic Association embracing outstanding orthopaedists in the United States is given by the list of original members. The first members came from Boston, Buffalo, Cambridge, Cincinnati, Denver, Hartford, Louisville, Minneapolis, New York, Philadelphia, and St. Louis. One would judge from the above that the original membership was well scattered around the United States. Boston appears at the head of the list on an alphabetical basis, and on that alone. New York apparently took good care at that time that in this matter at least, she should not be outstripped. Eighteen of the original members were elected from the New York district. Five were from Philadelphia and three from Boston. Youthful orthopaedic surgeons were apparently permitted and encouraged to speak freely at the

*Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 26, 1957.

meeting and they did so vociferously, although they were not granted membership until a later date. It is somewhat amazing to find recorded the papers of the very first meeting of June 15 and 16, 1887, published in Volume 1 of the *Transactions of the American Orthopedic Association* in 1889. These were printed by Kellogg and Son of Boston in an edition limited to five hundred copies. It is noted "that the type has been distributed." With the five hundred original copies, any chance of expansion of the first edition ceased. Of these Transactions, only a few complete sets still exist. They are prizes worth securing and protecting, they are without price, and they should be handed down from orthopaedic surgeon to orthopaedic surgeon. To place them in a library may relegate them to oblivion. The words they contain bring to life the authors. They should remain alive, with the living, not buried on a shelf.

Beginning with the first meeting, the material presented was highly provocative of argumentation. It seems clearly apparent that the men who joined the Association were the leaders in orthopaedic surgery in their communities, and yet, they themselves felt the need of improvement. Papers seem to have been presented not so much to advance knowledge as to form a basis for discussion. Uninhibited, and often heated, discussion there was. Guests joined freely in this discussion. This must have appeared quite satisfactory to the membership, since we later find many of those guests elected to membership.

Certain minor points, such as an article on the best way to hold an osteotome, or illustrations with the female figure veiled or so heavily draped that one cannot see the deformity described, cannot divert attention from the basic quality of the articles as a whole. The material from the start was outstanding.

A review of the Transactions indicates that very little of our modern surgical thought is new. Prostheses and implantations for numerous joints, with ivory used for the replacement, had been attempted before 1890 as recorded by DeForest Willard. Resection of tuberculous abscesses and joints as a method of treatment was recorded. While the problems of anaesthesia and sepsis limited performance, a study of the mechanics of deformity, the pathology of diseased conditions, the response to modalities of treatment at that time available, and speculation as to what could be accomplished in the future were rife.

Parts of the minutes of the executive sessions were published showing the gradual increase of membership, strictly limited as to numbers. There was slow development of the constitution, which always maintained the original tenets. The only real change was a progressive restriction as to qualification for membership.

Looking back on the original status and the gradual development of the Association one gains considerable respect for our elders. A struggle there was between the individuals, oftentimes bitter.

It seemed that from the inception such a struggle was planned. The whole purpose of the organization seemed to be to permit those at the top to come together with men of equal prominence who could, would, and did polish rough corners off the leaders in a way that could not be accomplished by local, younger or subservient confreres. The meetings originally were wholly scientific in nature. There is no record of banquet, dance, cocktail parties or other similar functions.

It is clear that unanimity of opinion, or personal friendship universally extended, was not a qualification for membership in this group. A wholesome respect for an individual's achievements, determination, and honesty was the determining basis for acceptance. Determination to refuse membership to an individual on the basis that the man was personally objectionable seems to have been a later development, at times overcome with considerable difficulty and offering a potential disaster to Orthopaedic Surgery as a whole. This, I feel, should be avoided in the future. May I quote the Scotch proverb: "A man is a man for all that, for all that"!

I have gone somewhat into the background of the development of The American Orthopaedic Association as a basis for what follows.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The American Orthopaedic Association was "established for the advancement of orthopedic science and art." Orthopaedic Surgery may be defined as that science which treats of the form and structure of organized human matter. One immediately considers whether or not the orthopaedic surgeon is concerned with the pathological structure of the human body. There is no question but what he is, but he is also concerned with the normal. A diagnosis of the pathological condition rests firmly on the basis of a knowledge of normal structure. It is fully as important to evaluate and advise the patient that the structures are normal, as to diagnose, evaluate and formulate a rationale of therapy and give a prognosis in an abnormal condition. The definition was purposely made broad since the orthopaedic surgeon cannot be limited to bone and muscle, but must consider pathological conditions of the nervous, the vascular and all other systems. He cannot limit his attention to an arm or a leg but must take the entire body into consideration. To my mind, this is what makes orthopaedic surgery fascinating. Its study encompasses the structures of the whole body and the body as a whole. One must envisage changes occurring throughout the body from the development of deformation and disease, or the reconstruction and arrest thereof. With transplantation of a tendon in the hand to a new location one alters pathways back to and including the brain cortex.

To state that our purpose is "the advancement of orthopaedic surgery" is a major premise which cannot stand alone. One must speculate on the term advancement. Advancement to what? May I propose an illustrative simile derived from aviation. One proposes to advance from New York to San Francisco flying on top of a solid overcast. One reaches the San Francisco area through various routes with the help of numerous aids. One still has not completed his advancement to San Francisco until he has let down through the clouds and reached the airport. Similarly, orthopaedic surgery to be advanced must travel by numerous routes, with great difficulty at times, coming down through a cloud of various activities, until it reaches the patient. The patient is the actual goal, the haven of perpetuation of any society such as ours. Too often advancement is based on improvements gained for ourselves, forgetting that permanency of advancement demands aid and benefits to others. Again may I illustrate. We insure for malpractice. Should we insure to protect ourselves or, in view of the certainty of human fallibility inherent in the surgeon which may result in damage, should such insurance exist, on occasion, to recompense the patient? We believe that in every act the Association must be responsible to the best interests of the individual entrusted to our care and through that individual to the community as a whole.

EDUCATIONAL FUNCTION

The specific educational function of The American Orthopaedic Association seems to me to be the polishing,—through disruption, if you wish—of scientific thought, and the improvement and realignment of concepts; the broadening of the experience of the leaders of orthopaedics who, in their home locales, can have no such experience. It is we ourselves who need knowledge and molding of opinion and nowhere else may this be obtained.

Discarding humility and accepting facts, by selection, the members of this Association are, or should be, leaders in their sphere of activity throughout the United States. Responsibility for the dissemination of knowledge automatically devolves upon us, in addition to the main responsibility of improving ourselves.

Education in orthopaedic surgery begins in the medical school. Advice as to the curriculum to be carried out and its interrelationship with other branches of medicine taught is a direct responsibility of ours. It is more important to influence the administration of the medical school program than to make a professor of orthopaedic surgery, *ipso facto*, one of our members. "Those who can, do; those who can't, teach." We do not accept this dictum; but let us be sure that those we accept both do and teach. A stronger liaison should be

formed with the American Association of Medical Colleges and similar agencies to let them know that orthopaedic surgery is not merely for the purpose of correcting deformation but also for preventing it. The rationale for the increasing assignment of the care of fractures gradually devolving upon the orthopaedic surgeon is not as well understood as it should be.

The Orthopaedic Section of the American Medical Association is probably the first forum to which the younger orthopaedic surgeon speaks. Too little attention to, and attendance at, the meetings of this Section is given by members of our Association. These meetings are of extreme importance and at them are always presented the very newest of concepts for review and discussion. We should have a report or review of the activity of this organization at our meetings. We are, by default, allowing an extremely valuable group of orthopaedic surgeons to pass entirely from under our sphere of guidance. We would suggest that the immediate Past Chairman of the Orthopaedic Section of the American Medical Association be invited to attend our Executive Committee meetings, as the immediate Past President of the Academy now does, and that both present a short review of mutually important problems.

The relationship of The American Academy of Orthopaedic Surgeons to our Association is extremely favorable. Interrelationship of the membership and a close contact of the Executive Committees keep each organization advised not only of actions taken but of actions pending. The Academy represents a graduate university of orthopaedic surgery, *par excellence*. At first it would seem that with its program of scientific papers, exhibits and cinematographic material our scientific sessions could be dispensed with. When one gets back to the original premise, however, that our membership needs polishing of personnel, readjustment of thought, and advance in knowledge suited to its own caliber, lack of conflict between the scientific sessions of the Association and Academy becomes apparent. The presentations before our assemblage should be longer in text, more controversial and provide not only assigned discussion, but a satisfactory period for uninhibited discussion from the floor. We are still attempting to have too many presentations and too abbreviated a period for discussion. Look back in the past and one will see that, originally, although the papers were limited to twenty minutes, there was no limitation on time of discussion. The paper was a focal point, the discussion frequently contained the real thought and the real advance.

The American College of Surgeons takes but little note of the orthopaedic surgeon as an entity. This is of little embarrassment to us but is directly harmful to the College. The College, like our Association, basically must be and is responsible to the individual submitting to surgery, and to the community, as regards the education and quality of surgical personnel. There can be no question of the tremendous field of benefit provided by orthopaedic surgery beyond that claimed or wanted by the general surgeon. It would seem wise to more definitely emphasize Orthopaedics at their Section meetings. This would provide the results of experience and the advancement of knowledge available from the orthopaedic surgeon to the general surgical membership. This, to us, seems an extremely important point. It is not a matter in which the Association or the other recognized orthopaedic societies demand a "place in the sun." It is a situation in which there is a potential of knowledge which can be freely offered and would prove acceptable. There already is an advisory committee of five of our members appointed as requested by the College. Perhaps this needs activation. A yearly report of the chairman of this Committee to our Executive Committee would seem indicated.

The medical societies, local academies of medicine and regional orthopaedic clubs are in need of basic orthopaedic knowledge. Requests to speak at such meetings should represent to our membership essentially a command. The size of the meeting should not be a criterion for acceptance of the duty imposed by a request for knowledge. Your President will never forget an occasion on which he read a paper entitled "Posterior Fixation of the

Fibula in Fractures at the Ankle" to three members at one of our Association meetings. The secretary, Dr. Robert Harris and Dr. Bruce Gill only were present; the others had left for that essential function—the Cocktail Party and Banquet. Never did I experience a more attentive audience, nor one more worthwhile. When one is a member of a family of leaders, one must never refuse requests for knowledge, barring actual physical disability.

The Research Foundation has been established by some of our members. Its birth has been so recent that the development of the child cannot yet be forecast. It deserves support. It will undoubtedly enable young men to carry out work that otherwise could not be done. I forecast, however, that a considerable amount of research, possibly the major portion, will still be produced, and will have to be produced, independent of its support. The word *research* has intrigued your President greatly in the past. To some it means the use of animals, test tubes, laboratory facilities, and a white coat. To me, research is any project of investigation which secures documentary facts and from them projects a new path for the future. Experience has taught us that in the past many of our greatest advances have been made by men struggling without support, hungry for knowledge and although whipped down by the exigencies of the situation, stimulated by their scientific urge and their enthusiasm to obtain knowledge. Money, at times, can preserve life but it has never been shown to be a decisive factor for buying brains.

Orthopaedic clubs and forums have been formed in the United States and others will be developed. They present a potential for educational improvement of unquestionable merit. They represent a desire for entire freedom of thought and action and do not have, nor should they have, any connection with any major parent organization, including ours.

The British Orthopaedic Association and The Canadian Orthopaedic Association have functions similar to those of our Association. They are autonomous and should remain so. Occasional dual meetings draw close the membership, one with the other. Advice from each to the others as to activities undertaken or contemplated can improve all. Separation of membership and activities can provide for freedom of action and independence of thought enhancing a friendly, competitive status beneficial to each.

SICOT (Société International de Chirurgie Orthopédique et de Traumatologie) is an international body to which some of our members belong, including your President. Its *raison d'être* is readily apparent. For the European orthopaedist it undoubtedly provides some of the benefits we desire through membership in our Association. The distance from its guiding leadership, the language difficulties, the size of its meetings, and the turmoil of its scientific sessions would seem to defeat its activities in the educational field. As an organization to promote the acquaintance of orthopaedic surgeons at the international level it would seem to function. While its title suggests an international role, its history, heritage, domination and conclave suggest that it actually represents the European orthopaedic surgeon and is essentially a European Orthopaedic Association. In any case, it should not, does not and cannot have a dominant role in relation to our Association!

PUBLICATIONS

It is difficult to visualize conditions at the time that the Association was first proposed and established. There was no official publication of orthopaedic surgery and, in fact, orthopaedic surgery as a recognized separate branch of surgery in the United States practically did not exist. The original membership consisted of thirty-five individuals. It was only raised within the ensuing few years to a total of fifty, yet 500 "pamphlets" of their Transactions were published. It is evident that the founders were well aware of their educational responsibility to the rest of the profession. The name *Transactions of the American Orthopedic Association* was changed to *The American Journal of Orthopedic Surgery* in 1903 and to *The Journal of Orthopaedic Surgery* in 1919. It was again changed to *The Journal of Bone and Joint Surgery* in 1922.

Up until 1954 when the American Academy became a co-trustee of The Journal, the

Association with a small membership of one hundred and fifty active members carried the financial responsibility of editing, publishing, and distributing up to 9,000 copies a year of *The Journal of Bone and Joint Surgery!* A direct assessment upon the membership above the amount of dues and almost equal thereto was made yearly for this purpose.

Originally, it was published by a commercial printer. In 1904, it was finally edited and published through its own offices and under the direction of a committee of its members. Before that time, manuscripts were collected and published through the efforts of the secretary of the Association. Finally, in 1916 a single editor was appointed. Since that time, Editorial Committees directed publication for only two short intervals, once in 1918 and again in 1943. The editors have been Mark Rogers 1916, Winnett Orr 1919, Elliott Brackett 1921, Murray Danforth 1943, Charles F. Painter (*pro tempore*) in 1943, and William Rogers 1944. It has been a tradition that the editor contributed, in the main, his time and effort. Never has an editor been satisfactorily monetarily compensated. Not only has the editor had to carry the worries of editorial work, assemblage of material and publication thereof, but also the tremendous responsibility for the financial integrity of The Journal. The present Editor, Dr. William Rogers, has actually given years of his life to this.

The Journal became the official publication of The British Orthopaedic Association in 1919 and of The American Academy of Orthopaedic Surgeons in 1935. With the incorporation of The Journal as the joint property of the Association and the Academy in 1954, the editor's financial worries became markedly reduced. His struggle to meet a set budgetary figure still remains.

The stability of The Journal has been remarkably increased by its present status as a separate corporation administered by a board of seven trustees, three appointed by the Academy and three by the Association, with an editor selected by six appointees. The Journal represents a valuable property, free of commercial pressures, self-supporting financially, and of the highest scientific standards. The Association should be justly proud of its origin, of its development to its present position in the scientific world, and of its assured future.

By further cooperation with The British Orthopaedic Association, and its membership throughout the British Commonwealth, The Journal came to represent the English-speaking world in Orthopaedic Surgery in 1948. The American and British Associations then agreed to a combined effort, each association to sponsor and publish its own issues. This combined effort continued after the Academy joined the Association in sponsoring the American issues. Financial responsibilities and editorial policies remain separate. The title *The Journal of Bone and Joint Surgery* belongs to the American corporation.

It is fortunate for many reasons that The Journal has no monopoly of publication of articles of orthopaedic interest. Limitations of page space alone would prevent satisfactory coverage. It would also prevent the publication and distribution of knowledge contained in many articles of value, and yet impossible of acceptance by The Journal. Furthermore, the fact of competition and the necessity of maintaining standards and improvement demanded thereby, are always of benefit. *Clinical Orthopaedics*, the journal published by the Association of Bone and Joint Surgeons, deserves the attention, advice, and support of the members of our Association. Papers of orthopaedic note appear in the *Journal of the American Medical Association* and in *Surgery, Gynecology and Obstetrics, The American Journal of Surgery, The Annals of Surgery*, state journals, society journals, and institutional bulletins. All these, as well as others not mentioned, are worthy of the attention of the well rounded orthopaedic surgeon. Efforts for the expansion of orthopaedic literature in all directions demand the assistance and guidance of our membership.

There are articles of superior value which appear outside of the pages of The Journal. A companion article, or a later article on the same subject following further investigation, should be secured for publication in The Journal.

Since it is obviously impossible for The Journal to accept all of the material offered, no feeling of discredit should be felt by an author upon refusal of his article. Your President, while a Trustee of The Journal, Treasurer of the Corporation, and an Associate Editor thereof, had three papers refused for publication in The Journal in one year. He is still enthusiastic about The Journal.

Of all contributions The American Orthopaedic Association has made, The Journal represents the peak of its achievements. Its value translated into the relief of suffering of the individual and benefit to the community, large and small, has been inestimable.

OTHER ASSOCIATIONS AND SOCIETIES

The origin and development of The American Orthopaedic Association should guide us in our reactions to the development of other societies such as our own. We were surgeons and became orthopaedic surgeons. We now represent a division of surgery, not a subdivision. Many groups within our own ranks have special interests. Many groups exist outside of our ranks with similar interests. It is not only our duty but to our best interests and the interest of patient and community to again furnish guidance, advice, and support. Such groups are the American Society for Surgery of the Hand, the Crippled Children's Bureau, the National Foundation for Infantile Paralysis, groups interested in spastics, in muscular distrophy, and other agencies. They are all trying to help. None of them should be discouraged. In our ranks are those who can provide guidance and assistance and lend direction to such efforts. Ours is, and should be, the association of the elders. By assisting others, in matters pertaining to orthopaedic surgery, we ourselves will continue to grow and develop. When we refuse to so assist, we decline in stature and knowledge.

PRESENT PROBLEMS

The problems presently arising in the Association are neither numerous nor great. Problems there will always be, however, in an association such as ours. Disclosure and discussion of them is the surest way of dispensing with them.

The American Board of Orthopaedic Surgery is essential and has done a magnificent piece of work. It needs perpetuation but it should not be in any sense self-perpetuating. The Association is responsible for a third of its membership. At the present time, we propose two names each year from whom the Board may choose one as a member and one as alternate. This may be to the Board's liking, but it is not to the liking of many members of our Association. We do not propose twice as many trustees for The Journal Board as may be necessary and allow The Journal of Bone and Joint Surgery, Inc., to select whom they please from the list. We direct them in their activities from our best judgment. It is the conviction of your President that a similar situation should obtain as to the American Board of Orthopaedic Surgery. One person should be selected, designated, and serve. The selection of the person to serve may be influenced by consultation with the Board, but final assumption of risk and responsibility of appointment should rest with the parent organization, The American Orthopaedic Association. The fact that we present three members to the American College of Surgeons, from whom they select one to represent us, does not invalidate your President's stand as regards the American Board of Orthopaedic Surgery. The American Board of Orthopaedic Surgery is, in part, our creation; the American College of Surgeons is not.

Efforts have recently been made to establish an American Board of Trauma. To date such efforts have not been successful due to the adverse opinion of the Advisory Board of Medical Specialties and the Board of Orthopaedic Surgery and its parent associations. Trauma is too wide a field and crosses too many lines to be established as an entity. It is not selective as to location in the body or result. One would have to have a board of trauma of the thoracic cage, another of the abdomen, another of the extremities, another of the blood supply, and so on. Despite the illogical assumption of those proposing a

board of trauma, considerable pressure for its formation has existed and undoubtedly will continue. The Association will have to maintain strict vigilance in the future in regard to this matter.

The size of the Association is important. An increase in size can denote decrease in quality. There are reasons for believing that the present size is already unwieldly and, perhaps, unnecessary. The present membership, with invited guests, already strains the accommodation facilities of the places to which we are accustomed, as well as those many places where we would like to meet.

Your President, during his five years' tour of duty on the Membership Committee, noted that almost without exception a satisfactory number of vacancies existed for the really qualified candidates proposed. That extra places are required now for expansion is questionable. With the thesis requirement, the membership will probably not increase in number in any case. The present size already defeats somewhat one of the purposes of the Association, namely, the close and intimate contact of the leaders in orthopaedic surgery one with the other. Part of this close association has already been lost. Your President would propose that the membership roll be frozen at its present figure, if indeed it be not again reduced to that of 150 active members.

There is still some resistance to maintaining the requirement of the submission of a thesis for consideration of a candidate for membership. Undoubtedly, review of such a thesis imposes a burden upon the Membership Committee. Theses provide, however, a very good way of evaluating the applicant. The society is formed upon the tenet that scientific orthopaedic papers be presented and discussed. If those proposed for membership are incapable of providing a satisfactory thesis, they are incapable of discussing such a thesis. In no way could such applicants contribute their share to the development of thought and knowledge demanded by our membership. Let us not forget that we attend these meetings, most of us, as the only place at which we can be reached and challenged by our equals and profit thereby. We must return to our own locales with a greater amount of knowledge to share with younger confreres, students, and patients. Arrangements for presentation of these theses, after their acceptance and nomination of the individual to membership, should be made. If the thesis is acceptable it should be worthy of delivery; if it is not worthy of delivery, it is not acceptable. By their works shall ye know them!

The Vice-President in the past has been seen but not heard. At this meeting we have suggested that your Vice-President, one of the most honored of our members, be heard. It is our hope that in the future this custom may be established and persist. The knowledge that the Vice-President will address the Association will provide a challenge for your President, and I am sure his discourse will prove of interest to the membership.

STATUS OF MEMBERSHIP

Membership in The American Orthopaedic Association is a privilege not a right. It is an honor to be accorded. It may not be earned. It is perfectly possible that a lifetime of very meritorious service may be performed by an individual who never becomes a member of the Association. No discredit should be attached to non-membership. Those elected should remain productive, a situation which frequently does not hold true. Further responsibilities, not less, are demanded by the privilege of membership. No one should feel justified in struggling for scientific attainment until membership devolves upon him and thereafter become non-productive. A member of our Association must not only continue to study, teach, investigate and report, but must assume willingly many other responsibilities devolving through such membership.

ASSOCIATION ACTIVITIES

The scientific program has been reduced in proportion to the length of the meeting. Originally, there were four sessions in two days, morning and afternoon. There are still

four sessions, but in four days. The program should be lengthened, though not, perhaps, to the original concept. Definite consideration of this matter should be undertaken. Your President would suggest that the time for individual papers be not lengthened beyond twenty minutes, but that discussion time be increased to at least the time required for presenting the paper. Half of the time of discussion should be assigned to the floor and the discussion from the floor should be strongly stimulated. The morning sessions should be lengthened or afternoon scientific sessions should be re-established on two of the four days. If we are to continue as a strong parent organization, it will not be due to extra-curricular activities but to devotion to the original concept of advancement of the art of orthopaedics.

It would be your President's feeling that on Sunday the time from 10:30 A.M. to 12:30 P.M. should be kept free of all scheduled professional activities to make it possible for those who so desire to attend divine services.

The Journal of Bone and Joint Surgery is now on an excellent factual business basis. No relaxation of inspection of the quality of The Journal or of suggestions for its improvement should be allowed to develop. We are the elders, but let us not go to sleep. It would seem that following a report of the Editor and of the President of the Board of Trustees at our business session, discussion from the floor was in order. In some fashion, the membership must develop a voice in this matter and keep it vibrant.

Those enjoying the Traveling Fellowship, developed by the Association for the younger members of our profession, visit England. The Traveling Fellows from the British Commonwealth visit America. It would seem to your President that our young men are limited in two ways. They come from one locale and go to one locale. The British fellows come from a considerably expanded Commonwealth and visit the United States. I would suggest that some consideration be taken in the future as to our American proteges expanding their route of travel. They should go for two weeks of their trip to the Continent, to well known centers of medical education and then spend four weeks in Great Britain. The exact division of time is not as important as expanding their route of travel and widening their horizon as to the European area. Certainly, past experience has proved that those who proposed the Traveling Fellowship were right. Our monetary investment has been well repaid. It should continue.

A word of caution is indicated. It is natural that some association of Traveling Fellows should be formed, such as the A.B.C. Club. Great care should be taken that this club's activities be of a social nature only and not directed otherwise to the advancement of its members. These Fellows are marked men. While they should be, and undoubtedly are, chosen on merit, many other young men, equally able, cannot be granted this distinction. The opportunity provided to travel confers no right to distinction in perpetuity. Let the Fellows continue to work and produce in the future in all humility, asking and accepting no especial advantage over others who, by chance only, may never have had this opportunity.

I would like to propose a few further words as to our Social Activities. These should, by plan, be subservient to our Scientific Program. At the present time they have developed to a point where individual or small group contact is impossible. Little, if any, time is left for close contact with one's friends. Organized cocktail parties for the whole membership and guests are planned for every evening preceding dinner. No longer can one select a few of his intimates to join him before dinner in an informal manner as heretofore. Planned evening entertainment is arranged. It would seem that some of the above could be dispensed with in an Association such as ours. At least one night should be free, preferably two.

As a youngster attending church I used to wake up with the last hymn. This is the last hymn! How best will the Association survive? I believe it can survive only if it serves. It has developed and existed by being an organization comprised of the more mature, established representatives in orthopaedic surgery who had a need to get in close contact

with confreres of equal and respected ability, with whom they could confer as to their problems and from whom they could expand their knowledge. Simply said: We are in need of return to the original principles: more work, less play.

1. Transactions of the American Orthopedic Association. Vol. I, p. 1, Boston, Published by the Association, 1889.

(*Continued from page 1419*)

blood supply. In the control group, necrosis of the head was obtained except in one of two cases in which the ligamentum teres was left intact.

To introduce circulation into the head the following grafts were listed: omental, vastus lateralis, glutaeus medius, glutaeus minimus, and rectus abdominus. In twenty-four mongrel dogs, the glutaeus medius or glutaeus minimus was used as a graft. After zero to sixty days, four microcuries per pound of body weight of P^{32} were injected intraperitoneally. The animals were sacrificed 100 hours after injection of P^{32}. The operated and normal hips were removed and sectioned vertically for counts by an end-window Geiger counter. An increased uptake was apparent in the hip with the muscle graft after twelve days which, according to the table of results, corresponded to the time that beginning or early "clinical healing" was evident.

A Report of Forty Cases of Impacted Fracture of the Femoral Neck Treated without Fixation. Dr. Henry B. Crawford [7] reviewed the literature on impacted fractures of the neck of the femur quoting Royal Whitman, Key and Conwell, Watson-Jones, and Per Linton. He believed that if roentgenograms reveal good impaction and there is no acute pain on motion, it is fair to assume that impaction is solid. He reported that in forty cases treated without fixation the hip was apparently stable and comfortable. He avoided the frog-leg position for lateral roentgenograms for fear of disimpaction, and painted the word *fragile* on the anterior surface of the affected thigh. As soon as comfort and agility allowed, crutch walking without weight-bearing was instituted. No weight-bearing was permitted until there was roentgenographic evidence of solid bone union. He warned his patient of a calculated risk of disimpaction.

Of the forty cases, thirty-seven united with solid bone union without loss of position. Two became disimpacted in the first four days of treatment; these were reduced and nailed and excellent results were obtained. One patient died eight months after injury; at six months, union was not firm.

Dividing the cases according to Pauwel's classification, all in Group I united; two in Group II became disimpacted; in one fibrous union was developing when the patient died. Of the four cases in Group III, all united, even though two were impacted in varus.

The author felt that the amount of pain the patient had with motion is a much better indication of the stability of an apparently impacted fracture than is Pauwel's angle. He did not feel that one would have been justified in nailing twenty-six fractured hips to prevent three of them from becoming disimpacted. He stressed the importance of watching for signs of disimpaction so that early reduction and nailing could be carried out.

Unicameral Cysts of the Long Bones. Treatment by Crushing Cystic Walls and Onlay Grafts. Dr. Carl E. Badgley [8] reported that multiple recurrences following the treatment of unicameral cysts of long bones by the accepted method of curettement and filling the cavity with bone grafts led him to review forty cases that had come under his observation. It was apparent that as long as the cyst was adjacent to the growing epiphyseal line, it remained in an active phase and recurrences following treatment were frequent. Attention was also called to the frequent resorption of bone grafts placed in an intramedullary position in the treatment of these cysts. If treatment was postponed until the cyst had entered a latent phase (that is, after it had been pushed away from the growing epiphyseal line by new-bone formation, or after the epiphyseal line had closed), recurrences were less frequent. Also, the author found that if the cysts were obliterated by crushing the cystic walls and onlay bone grafts were applied subperiosteally, healing with substantial bone formation was more satisfactory. Eight cases had been treated in this manner with good results.

These observations led the author to conclude that the cyst itself is of only secondary importance and

[7] 35 Chestnut Street, Rochester 4, New York.
[8] 1313 East Ann Street, Ann Arbor, Michigan.

that the essential pathological condition was a temporary impairment in the ability of ossification at the epiphyseal plate. It was his opinion that it was this failure of the formation of bone that led to the development of the cyst. Regardless of treatment, the cyst would continue to form so long as there was failure of ossification at the plate.

The author did not attempt to explain the nature of the defect in ossification at the epiphyseal plate but he felt that primary attention should be directed to this defect rather than to the cyst itself. His recommended operative procedure was based on the recognition of the osteogenic properties of periosteum and the subperiosteal tissue. Treatment consisted in abolishing the cyst by crushing the walls, freshening the bone, and applying bone grafts subperiosteally. He cautioned against excising the cyst since it would cause loss in continuity.

In discussing Dr. Badgley's presentation, Dr. Keene O. Haldeman [9] called attention to the fact that although pathological fractures through a unicameral bone cyst would heal, the cyst rarely was obliterated in the healing process. His treatment had been thorough curettement followed by packing the cavity with bone chips.

Dr. Rufus H. Alldredge [10] agreed that surgical treatment was more likely to fail in the younger patients in whom the cyst was in an active phase. He called attention to his observation that some unicameral bone cysts responded satisfactorily to almost any method of treatment, even radiation; therefore, one must be cautious in evaluating results of treating this condition. In 152 cases which he had reviewed, the most satisfactory method of treatment had been resection and the next most satisfactory method had been thorough curettement followed by filling the cavity with massive bone grafts. Pathological fracture frequently resulted in improvement but seldom a cure.

Mobilization of the Tarsometatarsal and Intermetatarsal Joints for the Correction of Resistant Adduction of the Fore Part of the Foot in Congenital Club-Foot or Congenital Metatarsus Varus. Dr. Clarence H. Heyman [11], Dr. Charles H. Herndon [12], and Dr. Joseph M. Strong [13] discussed a method of correction of resistant adduction deformities in the fore part of the foot. This procedure was recommended for children from three to seven years of age, in whom the adduction of the fore part of the foot had persisted in spite of repeated manipulations or applications of wedging casts. The operation consisted in mobilizing the bases of the five metatarsal bones through the tarsometatarsal articulations. The tarsometatarsal and intermetatarsal ligaments and joint capsules were completely divided. A transverse incision was made over the dorsum of the foot beginning at the medial side of the first metatarsal joint and extending to the base of the fifth metatarsal bone. The skin flaps were retracted and the entire metatarsal joints were exposed. After release of the joint capsules the fore part of the foot was manipulated into abduction and a well molded plaster-of-Paris cast was applied to hold the fore part of the foot in as much abduction as possible but without everting the heel.

Two weeks postoperatively, the cast was changed and the second cast was allowed to remain on for three months. Weight-bearing without the cast was permitted at the end of this period.

The authors presented slides and roentgenograms of twenty patients on whom this operation had been performed in the past twelve years. Twenty-nine operations had been performed. Nine patients had bilateral involvement. Nineteen of the results were considered excellent; six good; and three, fair. One patient had a poor result by the authors' classification. This is a simple procedure which can be performed at an early age with quite uniformly satisfactory results and without recurrence of the deformity.

Dr. Hiram Kite [14] stated that he had tried the operation on one child with resistant club-foot and had been pleased with the ease of the operation and with the amount of correction obtained. He emphasized if club-foot were properly treated, that is, if adduction of the fore part of the foot were corrected at the beginning of the course of treatment, there would be no need for this operation.

The Operative Management of Central Fractures of the Acetabulum. Dr. Robert A. Knight [15] and Dr. Hugh Smith [16] stated that the important principle of treatment of joint fractures is applicable to acetabular fractures; namely, the more anatomical is the reduction, the more nearly normal the result. This ideal can be approached only by open reduction and internal fixation in the majority of cases. From 1949 to June 1957, eight patients with central fractures of the acetabulum were treated by open reduction with encouraging results. It was not possible to restore the acetabulum adequately in every patient and late degenerative changes may occur even with good restoration.

[9] 350 Post Street, San Francisco 8, California.
[10] 1538 Louisiana Avenue, New Orleans, Louisiana.
[11] 2676 Berkshire Road, Cleveland Heights 6, Ohio.
[12] 2065 Adelbert Road, Cleveland 6, Ohio.
[13] 409 East Avenue, Elyria, Ohio.
[14] 490 Peachtree Street, N.E., Atlanta 8, Georgia.
[15] 869 Madison Avenue, Memphis 3, Tennessee.
[16] 869 Madison Avenue, Memphis 3, Tennessee.

There is no typical fracture. Fortunately, a rather large segment of ilium at the apex of the acetabulum was usually intact. The major fracture line was either vertical or horizontal, and comminution was common. A fracture elsewhere in the pelvis, a sprain, subluxation, or dislocation of the symphysis pubis, or of the sacro-iliac joint accompanied this injury.

Stereoscopic, anteroposterior roentgenograms were essential and were studied carefully to ascertain the location and type of acetabular fracture.

The authors' experience was not sufficient to make positive statements in regard to indications for operation, but any reasonable effort to restore a congruous acetabulum is worth while except in poor-risk patients.

The primary objective was reduction and fixation of the fractures which involve the weight-bearing vault of the acetabulum. Dislocation associated with central fractures of the acetabulum should be promptly reduced by manipulation and skeletal traction. Open reduction should be done four or five days later. An anterior approach is used for horizontal fractures and a posterolateral approach for vertical fractures. The fragments were reduced and fixed with Knowles' pins, screws, plates or staples. Following operation, care is simplified and morbidity diminished.

End results were not given because of the small series and limited follow-up, but, in general, they were superior to those from manipulation and traction alone.

A Histochemical Study of the Repair of Experimental Fractures. Mr. Robert B. Duthie [17] demonstrated by means of metachromatic staining and by labeling with radioactive sulphur in radioautographs:

1. The accumulation of mast cells at the fracture site in rats from forty-eight hours to fourteen days following fracture, and pointed out their significance in secreting a histamine-like substance with its possible trigger role in the mechanism for cellular differentiation after injury.

2. The increased deposition of the labeled sulphated mucopolysaccharide complex-chondroitin sulphuric acid, in the fracture defect from seven to twenty-eight days following injury.

3. That although estrogens, parathormone, thyroxin, and hypervitaminosis A had minimal influence on the initial stages of fracture repair, cortisone acetate was seen to affect the formation of the periosteal cartilage nests and the subsequent process of endochondral ossification. On the other hand, the local application of hyaluronidase and a histamine liberator that disrupts mast cells (compound 48/80) retarded the cellular differentiation occurring in the initial stages of fracture healing. Ligation of the main blood vessels appeared to retard the later stages of fracture repair. Intramedullary nailing apparently had little or no effect, except in preventing the formation of the internal callus.

Vice-Presidential Address

BY CHARLES LEROY LOWMAN, M.D., LOS ANGELES, CALIFORNIA

I am privileged to have this opportunity to thank you for the honor you have bestowed on me in electing me to the Vice-Presidency. This honor I realize was not given lightly and is the source of deep gratitude on my part. Also, I feel honored by the generous gesture of our President in having me take this part in the program.

It has been suggested that I indulge in a few reminiscences about the "old timers" I had occasion to meet in my earlier days and tell of some of the changes in orthopaedics I have seen take place.

When I look back on my first trip to Boston in 1908 and recall Dr. Bradford, Dr. Augustus Thorndike, Dr. Lovett, Dr. Painter, Dr. Brackett, Dr. Goldthwait, and Dr. Osgood, I realize keenly the great contributions these men have made to the science and art of orthopaedic practice.

Dr. Robert Osgood got me an appointment to the Massachusetts General Hospital in 1908. Dr. Painter introduced me to Carney Hospital the same year and, in 1915, in conjunction with Dr. John Lincoln Porter, of Chicago, sponsored me for membership in this Association. My application was signed by Dr. Robert Packard, of Denver, father of my friend, Dr. Robert Packard, Jr.

One of my most treasured visits was to Dr. Ansel Cooke, in Hartford, in 1908. There I saw how he made special shoes over plaster casts for the correction of pronated flat feet. I am sure that many here will recall his inimitable stories told in his typical drawling voice at our annual banquets.

Well do I recall the day during 1908 when Dr. W. R. MacAusland, working at Carney Hospital, had Dr. C. B. Francisco take me to the basement to learn to strap the flat feet of Irish domestics and policemen from 9:00 A.M. until noon. When Mac heard that I was leaving the hospital, he said, "Stick to your foot work and it will pay your office rent." That is exactly what I did. Carving plaster foot models and fabricating arch plates was an excellent background for later foot surgery.

[17] Royal National Orthopaedic Hospital, London, W.1, England.

I met Gibney, Whitman the elder, and Kleinberg in New York about 1911 at the old Hospital for the Ruptured and Crippled. There I saw Whitman do his famous astragalectomy and heard his dissertations on how to treat fractures of the femoral neck by the Whitman method. While in New York I enjoyed visiting Walter Truslow of Brooklyn. We were both interested in body mechanics and had the background to make us appreciate the teachings of Dr. Goldthwait and those of the Boston school.

In Baltimore it was interesting to meet Dr. Baer and Dr. Bennett. I recall a story of Allen Voshell's about a time when Baer was reducing a congenital dislocation of the hip and lecturing to students. He cautioned about gentleness and the dangers of fracture when suddenly there was a snap, and just as suddenly he said to Dr. Voshell, "Put on the cast."

About 1913, I had the good fortune to see Dr. G. G. Davis, of Philadelphia, do his horizontal transverse section of the paralytic foot with backward displacement. Whitman had put the idea of foot stabilization on a sound basis. But Whitman's reputation for rudeness was quite true as I can testify personally.

Around 1915 I was the guest of Dr. Michael Hoke for a week and quite literally sat at his feet. At night we would sit on the library floor so that I could watch him take a large sheet of fresh manila paper and sketch accurately the outlines of the skeletal reconstructions of the day. He brought out his first paper on his triple arthrodesis of the subtalar joint about 1921.

During the late 'teens and early twenties the arguments at our meetings waxed and waned and, in regard to the question of treating fractures by open or closed repair, often resulted in heated argument.

Frequently discussed were the pros and cons of treatment of congenital dislocation of the hip—whether open operation was better than closed, which method caused less shock, and which might result in a stiff hip. Very early in the controversy Dr. Galloway, of Winnipeg, and Dr. W. R. MacAusland were for open reduction while many others were for closed reduction. Dr. Ridlon, of Chicago, after listening to a heated discussion on this subject, called in an old police officer who had been walking a beat for many years. He then showed the roentgenogram of the officer's moderately dislocated hip to prove his point that no surgical interference was needed.

The subject of fractures, other than fracture of the hip, was equally controversial, with arguments and demonstrations for and against open or closed reduction. Once, during such a session, Joe Freiberg's father rose and disagreed with a speaker and, in his kind, gracious voice, laid the young man low.

I shall never forget the luncheon at Dr. Brackett's home at the beginning of World War I. About a dozen of the younger men who were invited were told of the need of men in England and that Robert Jones wanted help. It was a great disappointment to me not to be able to volunteer. Later, in 1918, after a visit from Dr. Osgood, I received a request from the Surgeon General's office to be examined for home duty. I was processed, received a commission, and was ordered to Camp Fremont Base Hospital—then to Letterman. It was while serving there that I received a telegram offering the present property as a site for the Orthopaedic Hospital of which I had dreamed.

In the Midwest, Dr. Griffith, of St. Louis, and Dr. Lord, of Omaha, were the pioneers. Dr. Lord was one of the first of the Association's members to visit me in Los Angeles. He visited us in the early days, just preceding the building of Orthopaedic Hospital, when, in 1919, we still held our clinic in the old Brockway stable. I remember his confirmation of a diagnosis of tuberculosis of the hip in which Perthes disease co-existed. On one of his visits he spoke to our Los Angeles Orthopaedic Society of about a dozen members and was made an honorary member.

Herbert Galloway, of Winnipeg, was another early member of this Association who visited our clinic and did an open reduction and shelf operation for us.

In those days Dr. Baldwin, of Salt Lake City, and Dr. Harry Sherman, of San Francisco, were my nearest neighbors. I was the only specializing orthopaedist between San Francisco and New Orleans and often consulted them by mail when I needed help.

I can look back on the evolution of the "hardware-and-gadgetry age" which began at the time of the use of the Lane plate. I recall seeing this used for the first time about 1915 at the Allegheny General Hospital in Pittsburgh, where Dr. Sherman was using it widely. Every meeting in those years had arguments for and against internal fixation, good and bad methods of plating, and metallurgical studies regarding oxidation and electrolytic reactions. There were presentations of good results and technical reasons given for poor results.

The accumulation of experience in the use of metals has led to their wide use. There is, however, an increasing tendency to conservatism after seeing the tragic results of poorly devised or executed procedures.

Many of the old-school orthopaedists may not have had as much technical surgical training as those of the present. Much of their success was based on their knowledge of the art of the practice, which in these days of appreciation of the value of psychiatric and psychological assistance, is recognized as psychosomatic medicine.

In the more material field, these early orthopaedists, although sometimes dubbed "strap and buckle men," were resourceful in the use of mechanical principles on the "do it yourself" style so talked of today.

Their ideas, passed down to the younger generation, have led to increased interest in gadgetry, a close cooperation with manufacturers of surgical equipment, and to increased interest in engineering.

The recent research in the prosthetics field that began during the war, has drawn the professions of medicine and engineering into close association. Twenty years ago this relationship was so appreciated by Dr. Arthur Steindler that he took a course in engineering.

I have delayed mentioning Dr. Steindler as he was not of the old school and is not my senior in age. But I consider him much my senior in intellect and accomplishment. He, like Goldthwait, has been an ardent promoter of the study of biomechanics. I have profited by the teachings of these two outstanding men, and I have received from them impetus to my work, especially on the subject of postural stress.

The major thought that I should like to leave today is particularly addressed to the younger men and to those who are teachers of students, interns, and residents. For years I have noted insufficient incentive or inspiration of many teachers in creating interest and appreciation of postural deviations.

Last summer at Banff, in a discussion with a highly qualified teacher in orthopaedics, we found ourselves in complete agreement on the lack of interest among residents. He said that his men showed a definitely bored attitude whenever he discussed the subject of body mechanics. It is important for a young orthopaedist to realize that if he wants to be known as a well grounded orthopaedic surgeon, and not simply as a bone surgeon or traumatologist, he must have good training in kinesiology and dynamic anatomy and be responsive to deviations occurring in growing children. He should become acquainted with school health services and be aware of the enormous load of postural deviations that lie in the physical education as well as the orthopaedic field. His interest will be welcomed and any help he can give these paramedical workers will bring him great satisfaction.

In helping to guide the correction of early biomechanical faults in growing children, he will lay a good foundation for their future health. He will also put on a firm basis his own future private practice. Other practitioners, internists, pediatricians, cardiologists, psychiatrists, and many more have long given attention to the preventive aspects of their respective specialties. I feel that orthopaedists should do the same.

If members of the American Board of Orthopaedic Surgery would evidence their interest by adding to the examination questions that deal with body mechanics, residents aspiring to pass such examinations would begin to prepare themselves properly. Their teachers would be motivated to help them develop a basic understanding of the problems of growth and development in children and make it possible for them to handle more effectively biomechanical wear and tear in their adult patients. They would then merit a growing reputation for fine service to their communities and, in their later years, find their former patients bringing in their children to them.

The Development and Significance of Femoral Torsion. Dr. W. J. Tobin [18] stated that torsion is a characteristic of all the long bones and that the term "anteversion of the neck of the femur" is anatomically incorrect inasmuch as torsion occurs throughout the entire femur and is not limited to the head and neck. Reference to the work of many authors established that there is great variation in the degree of femoral torsion. The extreme range was from +50 degrees to −25 degrees with the average varying from 11 degrees to 15 degrees in the individual groups.

An analysis of fetal development revealed that negative femoral torsion exists before three months, but gradually becomes zero at about three months. During the next three months the torsion tends to increase and in the third trimester there is a gradual derotation until an average of 30 to 35 degrees of anterior torsion is present at term. The cause of this was not explained but possible factors were discussed.

One case of congenital dislocation of the hip with marked anteversion of the head and neck was presented with a description of the postmortem findings. In this case the hip was better reduced with internal rotation, adduction, and extension. The possible relationship of femoral torsion to congenital dislocation was discussed.

The relationship of muscle imbalance to femoral torsion was briefly considered but it was not conclusively demonstrated in a causal relationship.

The role of femoral torsion in hip-fracture nailing was stressed as well as the possible relationship to congenital dislocation of the hip. No new or different theory was proposed to explain femoral torsion. Treatment of conditions in which obviously high degrees of femoral torsion existed was not discussed.

Torsion of the Femur. A Five-Year Report on the Use of the Dunlap Method for Its Determination. Dr. A. R. Shands, Jr.[19], and Cmdr. Marshall K. Steel [20] presented a four and one-half year follow-up report on the use of the Dunlap method for the determination of torsion of the femur. The report covered 1,409 roentgenographic studies of the hip joint on 584 patients made at the Alfred I. duPont Institute between August 1, 1952, and January 1, 1957. The technique of the procedure was described in *The Journal of Bone and Joint Surgery*, April 1953.

Of the 584 patients in this report there were "107 patients with 302 studies who had abnormal hips." These were as follows: "(1) congenital dislocation of the hip, forty-six with 142 studies (prereduction, twenty with fifty studies; postreduction, twenty-six with ninety-two studies); (2) dislocation of the hip

[18] 1835 Eye Street, N.W., Washington 6, D. C.
[19] Alfred I. duPont Institute, Wilmington, Delaware.
[20] U. S. Naval Hospital, Newport, Rhode Island.

associated with a neuromuscular disorder, nine with eighteen studies; (3) coxa plana, thirty-four with seventy-eight studies; (4) coxa vara, seven with thirty-one studies; and (5) miscellaneous conditions, eleven with thirty-three studies." Of the remaining 477 patients with supposedly normal hips, 249 were considered orthopaedically normal. The torsion readings of the roentgenograms of these patients, whose ages ranged from six months to sixteen years, were the basis for a graph showing the degree of normal torsion. In the normal graph the average normal in the first period of three months to one year was 39 degrees' torsion. At the end of the second year, this decreased to 31 degrees and then decreased from 1.4 to 2.3 degrees every two years until the tenth year when it was 24.1 degrees. From the fourteenth to the sixteenth year there was a sharp drop of 5 degrees, from 21.1 to 15.8 degrees.

The authors pointed out that there was considerable discrepancy between the present normals and those in the original article and attributed this to the fact that the roentgenographic technique varied in the earlier group and that many of the roentgenograms in the earlier group were made with a 35-degree abduction of the hip. In the determination of the femoral torsion, the variation of 10 degrees above or below normal was considered within the limits of error.

In congenital dislocation of the hip, there were forty-five patients with fifty-six dislocations. Eighty-three per cent of the cases had a torsion of 10 degrees or more above the normal. Three patients had one hip within normal limits. Thirty-six per cent were over 50 degrees, 19 per cent over 60 degrees, and 5 per cent over 70 degrees. The highest recorded degree of anteversion was 82. An interesting observation was the amount of excessive femoral torsion in the normal hip of the patient involved unilaterally. Forty-five per cent had 10 degrees or more above the average normal for the age period; the most excessive were 62 and 66 degrees.

The authors reported four girls who were followed two to four years after reduction and showed a decreased anteversion following reduction. In coxa valga, 60 per cent had an increase of 10 degrees or more above the normal average (shaft-neck angle 155 degrees or more). In patients with coxa vara, the femoral torsion readings were from −18 to 10 (seven cases recorded). There were thirty-four patients with coxa plana, twenty-four boys and ten girls. Six, or 15 per cent of the group of forty hips, had 10 degrees or more, increase of anteversion above the normal average for the age. In patients with cerebral palsy, there were twenty patients (forty hips); 67 per cent had an increase of 10 degrees or more over the anticipated average normal. The age period did not seem to make a great deal of difference. However, from this small number of cases, the authors felt that conclusions concerning age and increased torsion could not be drawn. In short lower extremities, most of the children with one normal extremity shorter than the other, a decrease in normal torsion was not shown. There were eleven cases of internal rotation in the legs of children with pigeon toes. All eleven of these showed an increase of the normal femoral torsion of 10 degrees or more. In patients with poliomyelitis and other neuromuscular disorders, there were 151 studies. There was no pattern of torsion determined and no significant findings were reported. There were no unusual findings in reference to torsion in thirteen cases of bow-leg. The authors compared their findings with findings of other groups in the literature.

Dr. H. Relton McCarroll [21] in discussion, said that it would seem that the accurate measurement of femoral torsion is primarily of academic interest in problems of congenital dysplasia and congenital dislocation of the hip. From a purely practical standpoint, the most important factor in determining the degree of femoral torsion in these patients is the finding of a position of stability for the hip at the time of reduction.

Dr. Harold Crowe [22] made a plea that in the presence of congenital dislocation of the hip that the opposite uninvolved hip not be thought of as normal, for in later years the hip that was called normal may cause more trouble than the hip that was dislocated.

Further Research on the Lumbar Disc. Prof. Sten Friberg [23] pointed out that in the majority of patients with low-back pain, the symptoms are associated with degenerative changes in the lumbar discs. A statistical study was carried out in Sweden to determine the effect of heavy labor on the incidence of low-back symptoms. When suitable corrections for age and sex were made, there was valid statistical evidence that the incidence of low-back disability was higher in those doing heavy labor, 64.4 per cent, than in those in sedentary occupations, 52.7 per cent. Severe disabling symptoms occurred in 10.6 per cent of those in heavy labor as against 6.8 per cent of those in lighter occupations. There was a definite correlation between increasing age and increasing incidence of back symptoms. Severe sciatic pain was also more common in laborers than in persons in sedentary occupations. It usually developed on an average of five to seven years after the onset of back symptoms. Although in the majority of the population studied the symptoms were not severe enough to result in lost time, the problem is obviously a major economic one, the collected figures indicating that there were approximately two million man days of work lost annually in Sweden as a result of low-back or sciatic pain. The economic loss in the United States, based on the incidence in Sweden, would amount to fifty million man days annually. In 15 per cent of those with symptoms, the onset was related to a

[21] 3720 Washington Boulevard, St. Louis 8, Missouri.
[22] 635 South Westlake Avenue, Los Angeles 57, California.
[23] Karolinska Institutet, Stockholm, Sweden.

definite accident, while 25 per cent related onset of symptoms either to the result of an accident or of heavy lifting.

Routine roentgenograms were made and the roentgenographic data were compared with the clinical findings. It was noted that roentgenographic changes in the form of narrowed disc space and spurring were late manifestations of disc degeneration and that they occurred about twice as often in laborers as in sedentary workers. There was no definite correlation between the presence of back symptoms and the changes noted in roentgenograms. There was also no correlation of back symptoms with the presence or absence of scoliosis, lordosis, or flat-foot.

Prof. Friberg then made some remarks on laboratory studies which a team of investigators had made on the effect of static and dynamic loading of the lumbar spine. He pointed out that prolapse of the nucleus pulposus through the vertebral end-plate could be produced regularly by applying suitable forces to the spine. He demonstrated by the use of discography and high-speed roentgenography the mechanism of production of the lesions. He believed that such end-plate fractures occur frequently and pointed out that they are difficult to demonstrate in routine roentgenograms.

Suppurative Arthritis of the Hip in Premature and Neonatal Infants. Dr. Benjamin Obletz [24] reported the end results of a study of suppurative arthritis of the hip in fifteen premature and newborn infants diagnosed and treated at the Children's Hospital in Buffalo, New York, during the years 1947 to 1956. Six of the patients were premature infants and the remaining nine were in their first few weeks of life. One had bilateral involvement.

In the six premature infants septicaemia and suppuration of the hip joint developed in spite of the exceptionally meticulous precautions and care rendered in the premature nursery of the hospital. Difficulty in recognizing the presence of septicaemia or of suppurative arthritis of the hip in newborn infants was emphasized. The importance of early diagnosis as offering the only reasonable hope of obtaining a good end result with satisfactory function was stressed. Dr. Obletz described the symptoms and signs to watch for in order to make a diagnosis before irreparable damage to the hip joint takes place. Dislocation of the hip was already present by the time diagnosis had been made in most of the cases reported. Osteomyelitis of the femur (ten) and ilium (four) was the source of the pyogenic organisms which infected the hip joints in fourteen of the sixteen hips. Hemolytic *Staphylococcus aureus* was cultured from eleven hips. Complete destruction and disappearance of the femoral head had occurred in eight of the sixteen hips. Of the seven hips which were treated by open drainage, only two of the femoral heads were saved. It was the author's opinion that this was because the damage had already occurred before the diagnosis was made and surgery performed.

He concluded by restating the need for early diagnosis, as well as early aspiration of the hip with culture to determine the organism and the most effective antibiotic. Open drainage by incision was advocated as soon as diagnosis of suppuration of the hip was clearly established. He suggested that antibiotics might succeed in a cure before serious damage to the hip joint occurred if the diagnosis was made very early. In the cases in which the suppuration was already present or advanced when the condition was recognized, antibiotics were of value but could not take the place of surgical drainage.

A Critical Analysis of Methods of Fusion for Scoliosis. An Evaluation in Two Hundred and Sixty-Six Patients. Dr. John H. Moe [25] presented a follow-up study of patients with scoliosis treated throughout a ten-year period; the majority of them were followed from two to eight years. The study was based on a total of 266 patients, and included both idiopathic and paralytic curves. The author based his result on an analysis restricted to a single curve, followed from the beginning of treatment to the end of the follow-up period. It was correlated with the cosmetic result obtained as well as the roentgenographic study. The cosmetic result was important since the improvement is sometimes noted even though roentgenographic findings appear to be minimal. Turnbuckle cast, Milwaukee brace, and a localizer cast, were the various methods used for correction. The localizer cast was used routinely for the past three years of the study. In regard to patients with idiopathic scoliosis, there were 130 cases. The average age at fusion was 13.8 years, the youngest being nine and the oldest, forty. The average gain in each patient was 45 per cent, and the results of 78 per cent were rated as good. The author pointed out that there was a difference in the incidence of pseudarthrosis depending upon the method of fusion used. As his method of fusion improved, the percentage of patients in whom pseudarthrosis developed fell from 60 per cent in the early cases to approximately 22 per cent in the later cases.

In the group of patients with paralytic scoliosis, 136 were analyzed; the youngest patient was three years old and the oldest was twenty. These patients showed an average gain of 44 per cent following fusion; those with a solid fusion maintained a higher percentage of gain than those in whom a pseudarthrosis developed. Out of this group, 49 per cent showed good cosmetic results. Of the whole series, 78 per cent were classified as good.

[24] 685 Delaware Avenue, Buffalo 9, New York.
[25] 91 South Seventh Street, Minneapolis 2, Minnesota.

In the paralytic group, pseudarthroses developed in 65 per cent of the patients with the early-type fusion, even with the use of autogenous grafts. This dropped to 30 per cent with the use of the later, facet type of fusion. There was a marked difference, however, within this latter group. Here, when a facet-type fusion and autogenous bone were used only 13 per cent had pseudarthrosis. When no bone was added, pseudarthrosis developed in 41 per cent. The author stated that the addition of the autogenous bone was extremely important. He stated further that bone-bank bone was usable but not as good as autogenous. The author made a careful analysis of the location of pseudarthrosis. He was unable to explain why the graft seemed to completely absorb in some patients, while in others, only single areas of breakdown seemed to occur. He concluded with the following: "Correction and fusion of the scoliotic spine is productive of results entirely satisfactory cosmetically and functionally provided that the proper fusion area is selected and the graft becomes solid and mature. The presence of pseudarthroses is the prime reason for loss of correction. Most pseudarthroses can be discovered, repaired, and protected until solid without appreciable loss of correction. A meticulous type of fusion with wide exposure, with all soft tissue removed from the posterior surfaces of the spine, with decortication carefully and completely done, and with facets carefully fused, is productive of the best over-all results."

Dr. Walter P. Blount [26] noted that the preparation of a paper such as this is a Herculean task. With a few exceptions, such detailed end-result studies have been conspicuously lacking in the past. Dr. Moe's 266 patients were not reviewed by means of questionnaires and punch cards; they were examined personally by Dr. Moe. Dr. Blount stated that it was not difficult to obtain the desired correction of a spinal curve if it is treated early before it becomes rigid. The exact method of postoperative immobilization makes little difference in the final result; the common problem is the loss of correction from pseudarthroses.

Cervico-Occipital Fusion for Congenital and Post-Traumatic Anomalies of the Atlas and Axis. Dr. Paul Lipscomb [27] discussed the problem of operative stabilization of the occiput and the first and second cervical vertebrae. He called attention in the region of the foramen magnum and the first and second vertebrae to known structural deviations of bone which may give rise to serious neurological deficits suggesting multiple sclerosis, syringomyelia, syringobulbia, or brain tumor. Among these anomalies may be found such congenital defects as platybasia, asymmetry of the posterior arch of the atlas, and a separate odontoid process. Recurrent and chronic anterior dislocations of the atlas on the axis requiring excision of part of the posterior arch of the atlas are among post-traumatic conditions. Infectious processes leading to progressive subluxation and dislocation of the first on the second cervical vertebra, may also be factors, especially in the presence of an anomaly. Surgical intervention by decompression through enlarging the vertebral canal may be clearly indicated in some of these to relieve cord symptoms. After decompression operative fusion may be necessary in order to stabilize the spine in this region. In the presence of some defects in the posterior arch of the atlas, especially following laminectomy and enlargement of the foramen magnum, fusion of the occiput to the spinous process of the second vertebra and possibly the third may be indicated. When the anomaly or injury is between the atlas and axis and there is no narrowing of the vertebral canal, as there is in dislocation. Fusion of these two vertebrae to each other is sufficient.

A series of nine patients was presented upon whom cervico-occipital fusion had been undertaken. Solid fusion resulted in seven of the nine and these were relieved of their symptoms. One in whom fusion failed to occur was improved and one was unimproved.

In discussion Dr. Joseph S. Barr [28] emphasized the necessity of fusing only the first and second cervical vertebrae in the presence of an intact first cervical neural arch. In this way stability is fully assured and the important occipito-atlantoid function is spared.

The Iliotibial Tract—Clinical and Morphological Significance. Dr. Emanuel B. Kaplan [29] presented a detailed analysis of the anatomy and function of the iliotibial tract utilizing six distinct methods; (1) the historical, (2) comparative anatomy, (3) human anatomy of premature and full-term infants as well as of adults, (4) electrical stimulation of adjacent muscles, (5) observations during and after surgical procedures, and (6) clinical observations particularly of paralyzed patients.

Anatomists from Vesalius down to modern times have been interested in the tensor fasciae latae muscle and in the tract. Although there has been some disagreement regarding the action of the muscle, Kaplan pointed out that the anatomists of the eighteenth and nineteenth centuries had an accurate understanding of the comparative independence of the iliotibial tract. Maissiat's monograph, though inaccurate in many details, emphasized the importance of the tract in maintaining the upright position. Of particular significance were the observations of Duchenne.

The studies in comparative anatomy included dissections of three rhesus monkeys, one lemur, two

[26] 324 East Wisconsin Avenue, Milwaukee 2, Wisconsin.
[27] Mayo Clinic, Rochester, Minnesota.
[28] 234 Marlborough Street, Boston 16, Massachusetts.
[29] 1001 Grand Concourse, New York 52, N. Y.

gibbons, one orangoutang, three chimpanzees, one gorilla, one American bear, one lion, several cats and dogs, one alligator, one iguana, and two bullfrogs. In none did Kaplan find a distinct iliotibial tract, although all had a tensor fasciae latae muscle. This led him to believe that the tract is an independent structure which developed as a result of the erect position in man.

In the human infant the tensor fasciae latae represents a part of the gluteal group. The iliotibial tract is represented by longitudinal fibers which are not entirely differentiated from the fascia lata. In the adult the fibers of the muscle blend into the fascia lata and deep surface of the tract. The glutaeus maximus, besides its trochanteric insertion, also inserts into that part of the iliotibial tract which is connected with the upper part of the lateral intermuscular septum. The tract is "actually stretched behind the tensor muscle between the iliac crest and the knee." It is "intimately connected with the intermuscular septum and the linea aspera from the greater trochanter to the supracondylar tubercle of the lateral condyle of the femur." Below, it is attached chiefly to the lateral tibial tubercle but also to the lateral border of the patella in front, and to the biceps muscle posteriorly.

Electrical stimulation of the tensor muscle gave the same results as those obtained by Duchenne, namely retraction of the fascia lata, internal rotation of the thigh with flexion forward and slightly outward. There was no observable action on the knee.

In surgical procedures removal of considerable portions of the fascia lata and of the tract did not cause changes in function but it was noted that the tract acted as "an accessory anterolateral ligament of the knee."

In paralytic contractures the abduction and external rotation of the thigh frequently attributed to the tensor fasciae latae and the iliotibial tract is due, according to Kaplan, to contractures of the glutaeus minimus and the anterior half of the glutaeus medius.

The author concluded: "The iliotibial tract . . . otherwise known as the iliotibial band, or the band of Maissiat, is a ligament connecting the ilium with the tibia. It is observed in its form in man and is associated with the erect posture. It is connected intimately with the tensor fasciae latae anteriorly and the glutaeus maximus posteriorly in the region below the greater trochanter. The femur is stabilized synergistically by the tensor fasciae latae and glutaeus maximus in standing and walking. The tensor fasciae latae pulls the tense band anteriorly in flexion, and the glutaeus maximus shifts the band posteriorly in forced extension. The band is, however, held by the lateral intermuscular septum, permitting a limited amount of anteroposterior motion. At the knee joint the band acts as a stabilizing ligament between the lateral femoral condyle and the tibia in continuity with the proximal part of the band. This stabilizing ligament is attached to the supracondylar tubercle of the lateral condyle as a fixed point and moves with the lateral tubercle of the tibia forward in extension and backward in flexion of the knee joint.

"The importance of the tensor fasciae latae and the iliotibial band was possibly overestimated as a deforming factor in cases of paralysis and contracture."

In discussion, DR. ERNEST GARDNER [20] said that electromyography confirms that the action of the tensor fasciae latae is confined to the hip and knee. Although Dr. Kaplan found no abduction on electrical stimulation of the tensor fasciae latae electromyography reveals a consistent response during abduction. Dr. Gardner doubted that the tensor fasciae latae acts synergistically with the glutaeus maximus in standing and walking. He also pointed out that the function of the iliotibial tract is largely mechanical but that it may also have a proprioceptive function.

Biomechanical Approach to Residual Crash Spinal Injuries. DR. JACOB KULOWSKI [21] discussed correlations between spinal injuries and the over-all mechanics involved in their occurrence in motor-vehicle accidents. Two hundred and fifty case records form the basis of the analysis; 100 of the injuries were cervical, 100 were of the back, and fifty were both cervical and of the back.

As pre-impact factors, static and dynamic stresses in riding in the sitting position result in fatigue involving the ligaments of the spine and symphysis, trunk musculature, the sacro-iliac and lumbosacral joints, as well as the intervertebral discs. These must be combined with inertial stresses incidental to maintaining balance when direction and velocity are constantly changed. Such stresses must be accepted by hip, abdominal, and paravertebral musculature. These various factors are increased by faulty seat construction and postural stresses.

Equally important, degenerative and rheumatoid arthritis in the cervical spine were present in 60 per cent of the patients, about one-third of whom were drivers. Since most of the collisions occurred at intersections where a wide range of vision is important, it was assumed that the restrictions due to the arthritic changes were causally related to the accidents in a greater-than-chance incidence. Drivers with cervical anomalies had more than twice [illegible] many rear-end and angular collisions as normal drivers. This was not true of drivers with thoracic, lumbar, or sacro-iliac defects. In the same class is spinal osteoporosis—a factor which predisposes to compression fracture in crash accidents.

About 80 per cent of accidents are collisions, less than 45 per cent being between automobiles. The

[20] Wayne University College of Medicine, Detroit, Michigan.
[21] 414 Corby Building, St. Joseph, Missouri.

injuries from these accidents comprise between 75 and 90 per cent of the total. Less than half of the cervical injuries were due to rear-end collisions.

About one-third of the injuries were known to be due to violent interactions between body segments as the result of the collision and about one-third were known to be due to impact of a body segment against an object outside the body. The car seat is the chief point of contact with the car and an important factor in injury production.

The percentages of roentgenographically positive injuries were as follows: 40 per cent in the cervical region; 26 per cent in the thoracolumbar region; and 22 per cent were mixed. These facts emphasize some of the problems the surgeon faces in disability rating and in evaluating his patients' claims.

The Synovial Membrane in Epiphysiolysis of Adolescence. Dr. George J. Garceau [32] and Dr. Robert E. Morrow [33] described four cases of slipped epiphysis in which biopsy of the synovial membrane was performed and changes similar to those described by Howorth found. The authors reviewed the evidence for a theory of pathogenesis of slipped epiphysis based upon the idea that the synovial changes are primary and the vascular changes similar to those occurring in the synovial membrane also occur at the epiphyseal plate, weakening it and predisposing it to failure. That the non-specificity of the synovial membrane differs when compared with changes found in many other conditions suggested to the authors that this condition was essentially a metabolic one, perhaps allied to collagen disease or to protein metabolism.

Dr. Mary S. Sherman [34] said in discussion that it was difficult for her to understand, on the basis of the observations presented, why the authors conclude that the synovitis is the primary process and the cause of the epiphyseal slipping. If it were so one might expect to see such an effect associated with other processes which produces synovitis, but such is not the case.

Dr. Garceau said, in closing, that the condition does affect other epiphyses. He said that in patients with epiphyseal slipping he had seen other epiphyses in other parts of the body affected.

Acquired Dislocation of the Hip in Cerebral Palsy: Etiology and Clinical Types. Dr. Winthrop M. Phelps [35] presented the causes, possible prevention, and a discussion of the treatment of dislocation of the hip in cerebral palsy. The importance of the abnormal muscle pull of the spastic or contracted gracilis was emphasized, and the author considered it a major cause of unilateral or bilateral progressive dislocation of the hip. The contracted or spastic gracilis is a knee flexor as well as an adductor and, with the knee held in extension either by plaster or by positioning, this muscle may cause constant adduction of the thigh. This adduction alone, or in conjunction with coxa valga, may cause erosion of the superior border of the acetabulum and result in gradual dislocation. Illustrations in the paper showed the gradual change in the acetabulum which occurred over a period of several years. The author emphasized that pain was usually absent during the time that this gradual dislocation occurred.

Dislocation which resulted from spastic adductors occurred without acetabular erosion and was usually associated with pain. The femoral heads appeared to be "rocked out" of the acetabula.

Coxa valga may occur in conjunction with the tight gracilis and spastic adductors or may be present without either. The persistence of the normal coxa valga seemed due to too late weight-bearing. Under these circumstances the pull of the glutaeus medius is almost vertical and hence is inefficient. A muscle imbalance between the abductors and adductors occurs. This imbalance predisposes to a lateral dislocation of the hip, as was shown in the slides.

Dr. Phelps believed that dislocation may be prevented by early myotomy of the gracilis or adductors. He also suggested standing the patient in braces at about ten months of age, in order to prevent coxa valga. If coxa valga persists, osteotomy for correction of the coxa valga and for correction of anteversion were mentioned by him but not elaborated upon. The author was not specific about the type of osteotomy considered, since it depends on the findings in each patient.

The paper was discussed by Dr. Frederic C. Bost [36] who thought that anteversion at the upper end of the femur was extremely important as a cause of the dislocation. It was his opinion that dislocation which occurred after adductor myotomy was probably due to the torsion factor. He mentioned use of the Colonna procedure in the older age group with persistent dislocation.

Dr. Lenox Baker [37] indicated that dislocation can occur in patients who have a combination of spastic gracilis, spastic adductors, and coxa valga. He emphasized the early use of surgery in order to maintain the extremities in a functional position.

Dr. William Cooper [38] said that he did not believe that the gracilis was as important a muscle as Dr. Phelps indicated. He favored intrapelvic obturator neurectomy for relief of the spasticity of the adductors.

[32] 23 East Ohio Street, Indianapolis 4, Indiana.
[33] 310 South Emerson Street, Indianapolis, Indiana.
[34] 3503 Prytania Street, New Orleans 15, Louisiana.
[35] 3038 St. Paul Street, Baltimore 18, Maryland.
[36] 384 Post Street, San Francisco 8, California.
[37] Duke Hospital, Durham, North Carolina.
[38] 535 East 70th Street, New York 21, N. Y.

In those patients who have persistent dislocation with pain, he described release of the abductor muscles along with release of the adductors and hamstrings.

The Surgical Correction of Congenital Elevation of the Scapula (Sprengel's Deformity). DR. WILLIAM T. GREEN [39] presented the operative method and the results obtained in sixteen instances of Sprengel's deformity. The operative procedure as described by Dr. Green was entirely an extraperiosteal dissection of those muscles which attach the scapula to the spine and the trunk. These muscles were completely freed in anatomical layers and were reattached after the scapula was brought down into its new position. If there was an omovertebral bone present, it was completely dissected out extraperiosteally at the time of operation. The supraclavicular portion of the scapula was excised along with the periosteum. The scapula was held down in place by wire traction applied to the spine of the scapula and attached to a small spring scale with three pounds of traction. This traction was maintained for three weeks, during which time the child was immobilized in a plaster spica. Then the child was allowed to return to activity. The author reviewed the previous surgical techniques and particularly compared this method with the extensive subperiosteal dissection of the scapula described by Dr. Schrock and a two-stage procedure described by Dr. Frank R. Ober.

Photographs of the patients before and after operation demonstrated the excellent results which were obtained by this procedure. Without exception, all the patients had been improved cosmetically and had better function of their arm after operation than before. Prior to operation, fifteen of the patients showed less than 120 degrees of combined abduction. After the operation, the average combined abduction was 167 degrees for an average gain of 49 degrees. In ten of the patients after operation, the elevation was essentially normal. The average caudad displacement of the scapula as interpreted from the roentgenogram was about four centimeters. One patient with bilateral involvement was described as having a very good displacement of the scapula caudad and excellent function of the arm in elevation, but had flaring of the lower end of the scapula indicative of serratus anterior weakness. Preoperatively, this patient was recorded as having weakness of the serratus anterior and lower trapezius with marked winging of the scapula.

The author's description of the operative technique contained many important items contributing to the excellence of the results. The technique had been varied to meet the individual needs of the patient. In some instances, the scapula had been osteotomized by a green-stick fracture to decrease its marked convexity. In all instances, the lower pole of the scapula was very carefully placed beneath a pocket formed beneath the latissimus dorsi. Considerable care was taken to reattach the various muscle groups so that they produced the desired downward displacement of the scapula. This was extensive surgery and one that required the attention to small details as given by Dr. Green, but as he stated, "it is precise, effective, and gives a most satisfying result."

[39] 300 Longwood Avenue, Boston 15, Massachusetts.

During the Meeting, Dr. George O. Eaton was inducted as President for the ensuing year. Officers elected were:

President-Elect: C. Leslie Mitchell, M.D., Detroit, Michigan;
Vice-President: Clarence H. Heyman, M.D., Cleveland Heights, Ohio;
Secretary: Harold A. Sofield, M.D., Oak Park, Illinois;
Treasurer: Mather Cleveland, M.D., New York, N. Y.

The next Annual Meeting of The American Orthopaedic Association will be held jointly with The British Orthopaedic Association at The Shoreham, Washington, D. C., May 11 to 16, 1958.

News Notes

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Waldorf-Astoria, New York City, February 1 through 6, 1958.

The Thirteenth Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Waldorf-Astoria, New York City, on Friday and Saturday, January 31 and February 1, 1958, under the Presidency of Dr. J. Edward Flynn.

The **Georgia Orthopedic Society** held its Annual Meeting at St. Simons Island on September 21 and 22, 1957 under the Presidency of Dr. Walker Jernigan of Atlanta. Dr. Fred Reynolds of St. Louis, Missouri, was guest speaker. The 1958 meeting will be held on September 13, 1958, at The Cloister, at Sea Island, under the Presidency of Dr. Robert McKnight.

The Thirtieth Semi-Annual Meeting of the **Tri-State Orthopedic Society** was held in Evansville, Indiana, October 25 and 26, 1957. The Spring Meeting will be held at the Greenbrier, White Sulphur Springs, West Virginia.

The Fifth Annual Meeting of the **Mid-Central States Orthopedic Society** will be held in Little Rock, Arkansas, March 20 to 22, 1958.

The Canadian Medical Association announces the publication of a quarterly **Canadian Journal of Surgery,** the first issue appearing in October, 1957. The professors of surgery in the twelve Canadian medical schools constitute the Editorial Board of which Dr. R. M. Janes, President of the Royal College of Physicians and Surgeons of Canada, is Chairman. Publication will be under the general supervision of the Editor of the Canadian Medical Association Journal.

Original articles in English will appear with a summary in French, those in French will have a summary in English.

The American Cancer Society has announced that clinical fellowships at the senior resident level for the academic year 1959–60 may be applied for by institutions accredited by the Council on Medical Education and Hospitals of the American Medical Association to give training in the following specialties and sub-specialties, with emphasis on the diagnosis and treatment of cancer: internal medicine, malignant disease, neurological surgery, obstetrics and gynecology, orthopaedic surgery, otolaryngology, pathology, public health, radiology, surgery, and urology.

Institutions will be notified of awards granted in June 1958. Individual candidates should apply to an institution or to the American Cancer Society for information concerning fellowships. The annual stipend, tax exempt, is $3,600.

Application forms are available from the Director of Professional Education, American Cancer Society, Inc., 521 West 57th Street, New York 19, N. Y.

February 15, 1958, is the deadline for institutions submitting applications for the 1959–60 clinical fellowships.

The **National Foundation for Infantile Paralysis** invites applications for post-doctoral fellowships in research, academic medicine, or in the clinical fields of psychiatry, rehabilitation, orthopaedics, the management of poliomyelitis, and preventive medicine. March 1, 1958, is the current deadline for applications. Financial support of the Fellow varies according to his previous education, his professional experience, marital status, and number of dependents.

Orthopaedic fellowships for advanced training in teaching or research or both are available from the National Foundation for Infantile Paralysis for those physicians who have completed the requirements for certification by the American Board of Orthopaedic Surgery or who have equivalent training. The age limit is thirty-six. Awards are made for a period of one year and are subject to renewal. All applicants must be citizens of the United States. Financial benefits, in addition to the compensation to the institution, vary from $4,500 to $6,000. Under unusual circumstances, higher stipends may be permitted.

In the management of poliomyelitis, awards are made to licensed physicians who wish to acquire a knowledge of the various aspects of the total care of poliomyelitic patients. A fellowship for one year for full-time study may be undertaken at any institution having suitable facilities and staff for this type of program. One year of internship is required. Financial benefits are $300.00 or $350.00 a month depending on marital status with $25.00 additional for each dependent child. Compensation to the institution is also arranged.

All awards are made upon recommendation of the National Foundation Clinical Fellowship Committee. For information write: Division of Professional Education, National Foundation for Infantile Paralysis, 301 East 42nd Street, New York 17, N. Y.

In a Main Entry in the Author Index, in brackets [ ] following the title, are listed references to information in the article not named in or implied by the title. All references in the Subject Index are to this Main Entry so that a person looking up any one reference to an article is led at once to all the indexed information.

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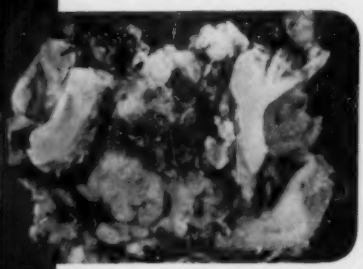

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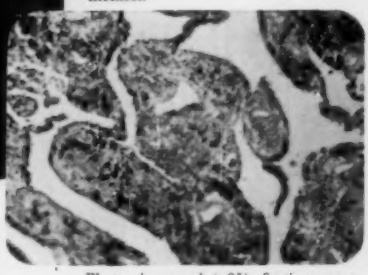

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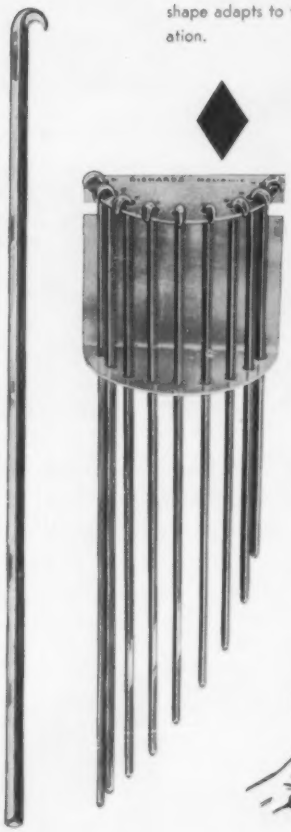

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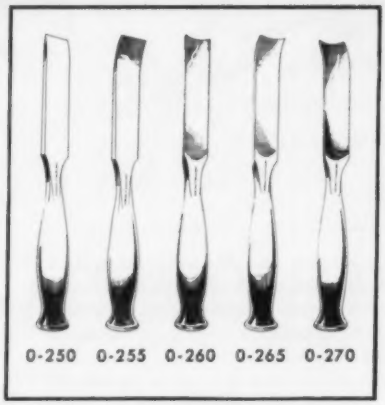

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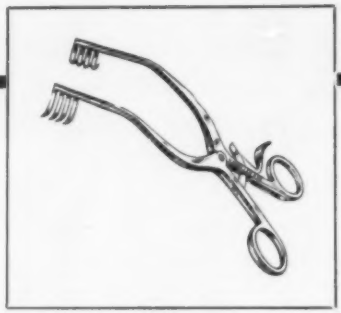

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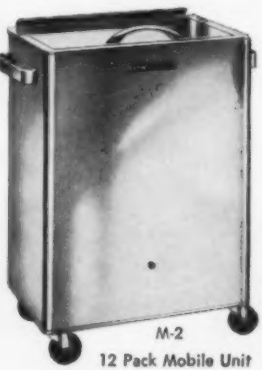

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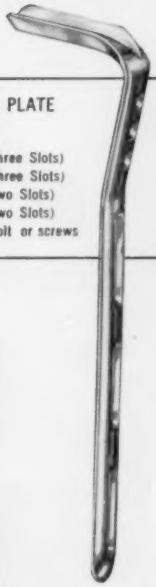

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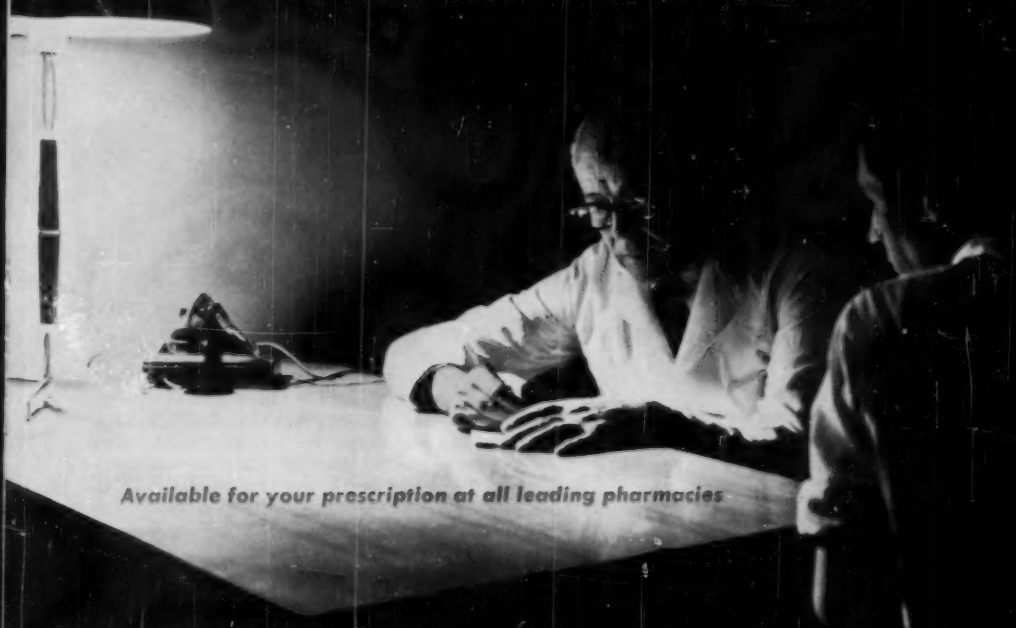

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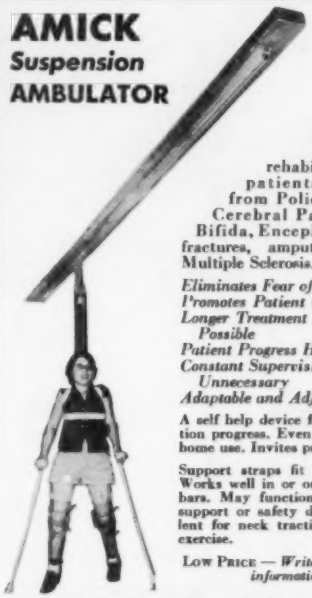

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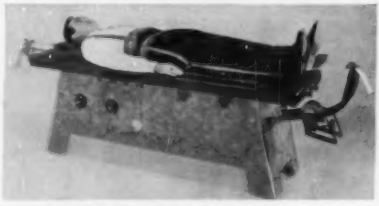

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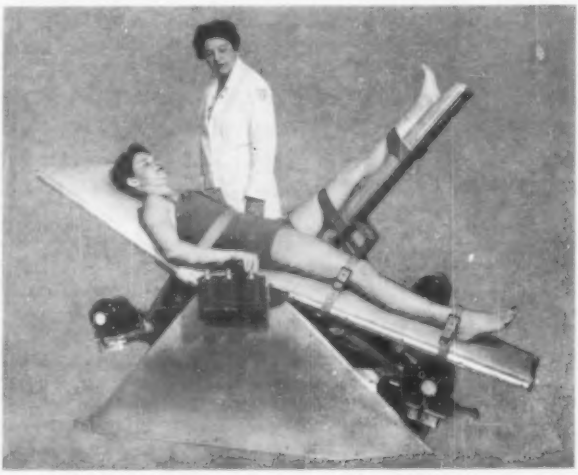

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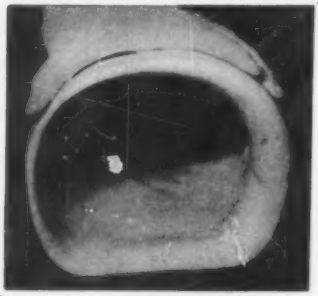

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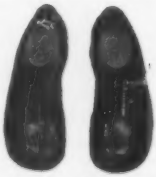

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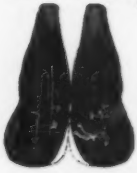

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